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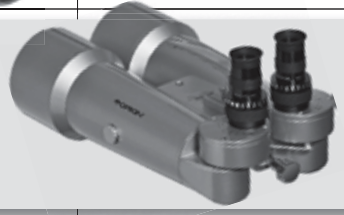

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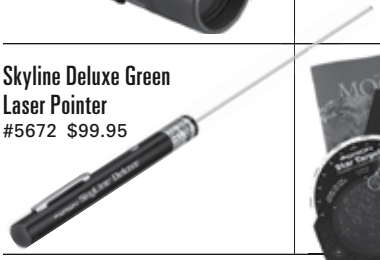

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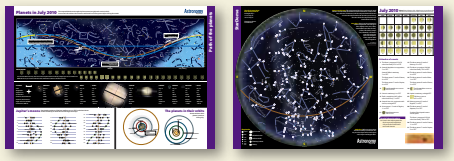

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Ron Miller for *Astronomy*

ON THE COVER

Astronomers look forward to the New Horizon spacecraft's arrival at Pluto. When it gets there, instruments aboard will study the planet and its three known moons.

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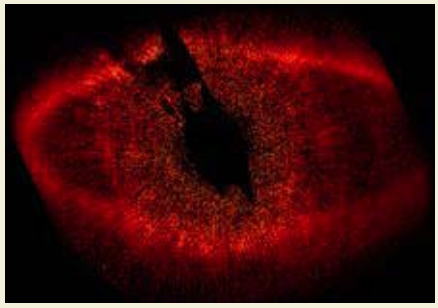

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Want to find a meteorite?

by David J. Eicher

If you harbor the desire to become a meteorite hunter, you may be in luck. From March 19–29, 2011, *Astronomy* magazine and MWT Associates will lead a tour called Tunisia: Rocks and Sands, In Search of Ancient Meteorites. This group will hunt for meteorites in the desert and see the magnificent wonders of this North African paradise. I will be delighted to accompany a select gathering of *Astronomy* readers on this trip. Mars researcher and meteorite expert Chris McKay of NASA's Ames Research Center will also be our expert guide.

We'll stop at Hammamet, a seaside resort on the beautiful Mediterranean, where we'll see castles and visit souks for shopping, where the most famous local offering is jasmine. The group will travel to Sousse, a far larger city on the coast that was known in Phoenician times as Hadrumatum. As we travel into the desert, we'll visit the spectacular Roman amphitheater at El Djem, built for 35,000 people around A.D. 238.

The group's southward movement will then take us to the old city of Sfax and onward to Tatahouine. This area was celebrated as "Planet Tatooine" in the *Star Wars* movies, serving as the setting of Luke Skywalker's home. In reality, the area was marked with importance more than 40 years earlier when, on June 27, 1931, a celebrated meteorite fell there that is now a treasure for collectors.

More than 12 kilograms of Tatahouine have been found thus far, and the meteorite is of special significance as it's a rare achondrite stone, a type called a diogenite. This rare type of meteorite is dominated by a mineral type called orthopyroxene, and astronomers have traced it back with a high degree of certainty to being a piece of the asteroid 4 Vesta.

Dhofar 1527, a meteorite found by Jim Labenne in the desert in Oman, in situ before it was picked up. Luc Labenne

We will continue our trek through the desert to see other historic Tunisian towns, and then return to Tunis. Exploring the ruins of Carthage will make one of the most memorable days of the trip. Because the Romans destroyed the culture and records of the Carthaginians at the end of the Third Punic War, this ancient city and its history are shrouded in some degree of mystery.

This will be a spectacular trip for any astronomy enthusiast. I look forward to joining you on it. For more details, see www.Astronomy.com/Tunisia.

Yours truly,

David J. Eicher
Editor

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A is for astronomy

I thought you folks at *Astronomy* might be interested in this picture of a potential "new recruit." Michael McMullen (Grampa) enjoys his subscription, as his grandson, Noah, joins in.

Grampa claims that Noah really liked the pictures in that issue of *Astronomy*, actually grabbing for them at 3.5 months old — and not just to ingest! I guess it's never too early to learn about the vast universe.

— Karen McMullen, Denver

Karen McMullen

Some readers prefer *Astronomy* for the articles, and some for the pictures.

Nebulous magnitudes

I'm having some trouble with seemingly conflicting information about the Crab Nebula (M1) from two separate articles in your December issue.

In your December story "Top 10 winter Milky Way treats," Senior Editor Michael E. Bakich says that "M1 has a high surface-brightness" and that it shines at magnitude 8.0. Toward the end of the same issue, Editor David J. Eicher says M1 is "relatively difficult to observe because its surface brightness is low," with a magnitude of 8.4.

Can you confirm which magnitude is correct and whether M1 has a high or low surface brightness? I ask because I have seen it with good clarity through a 6-inch scope in a nearby area just 10 minutes away, but I can't find a hint of it through my 10-inch scope at my present location. Was I just lucky last time? **— Joe Caggiano,** Glenside, Pennsylvania

Ah, nebulae! As our issue illustrates, you'll find various magnitudes for them, and each can be from a reputable source. That's because, unlike stars, nebulae are extended objects and therefore magnitudes are somewhat subjective. In many instances, we won't even list a nebula's magnitude. If it's small and bright, however, as in the case of many planetary nebulae or a supernova remnant like the Crab Nebula, we will.

As for M1's surface brightness, lacking a standardized measurement that would list magnitude per square arcsecond, such a trait is in the eye of the beholder. In fact, your observations confirm this. From one location, you saw it through a 6-inch scope, but 10 minutes away it was invisible through a 10-inch. Why? Well, it could be sky brightness, the presence of thin clouds overhead, cleanliness of the mirror or lens, the magnification used, or even the telescope's optical quality. So, based on your initial observation, you might say its surface brightness was high, but your second observation contradicts this. **— Michael E. Bakich,** Senior Editor

Hearing Herschel

While driving the other day, I happened to be listening to a classical music station, and what did I hear? A symphony by William Herschel, the great astronomer! And, better yet, it was a beautiful musical composition.

I was unaware that the discoverer of Uranus also had quite a musical career. He played the cello, harpsichord, oboe, and organ; served as the Director of Public Concerts in Bath, England; and composed 24 symphonies and numerous concertos. What a remarkable man!

— Rene Belzile, Quebec City

The Hippo Nebula?

In the February issue of *Astronomy,* you displayed the Horsehead Nebula in your "Beautiful Universe" section. The text says, "Few objects in the cosmos resemble their names, which makes the Horsehead Nebula a remarkable beast."

My 3-year-old grandchild disagreed, however. I believe the exact reaction to the picture was, "That's not a horsehead, it's a hippo!" And indeed, I now see a hippo running toward the light. I found this "discovery" so remarkable, I just had to share it. **— Rya Schuuring,** Utrecht, Netherlands

You're too good!

I write to request that you either stop improving *Astronomy* magazine at this breakneck pace of yours, or that you double your current page count. I still read other magazines because I, like many other enthusiasts, need more to peruse during the month. I fear, however, that if *Astronomy* continues to outdistance its competition, the other publication will wither away and cease operation.

Thanks much for your consideration.

— Robert Fields, Littleton, Colorado

We welcome your comments. Send letters to Astronomy *Letters, P. O. Box 1612, Waukesha, WI 53187; e-mail to letters@astronomy.com. Please include your name, city, state, and country. Letters may be edited for space and clarity.*

Astronomy magazine

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1. No Purchase Necessary. Official entry forms are bound in the June 2010, July 2010, and August 2010 issues of *Astronomy* magazine. The *Astronomy* and Celestron 2010 Summer Sweepstakes is open to residents of the United States and Canada (except Quebec) only, 18 years of age or older. Employees (and their dependents and immediate household members) of Kalmbach Publishing Co., their advertising and promotional agencies and sponsoring companies are not eligible to participate.

2. Sweepstakes Entry. To enter, complete and mail the official entry form or a postcard with your name, address, city, state or province, and zip or postal code to: The *Astronomy* and Celestron 2010 Summer Sweepstakes, P.O. Box 378, Waukesha, WI 53187-1199. Or enter online by filling in the Online Entry Form and hitting the SUBMIT ENTRY key. The Online Entry Form must be filled out completely to be eligible. Incomplete or defaced entry forms are void. One entry per household. The official ending date for The *Astronomy* and Celestron 2010 Summer Sweepstakes will be July 23, 2010, and all entries must be transmitted or postmarked no later than that date.

3. Prizes and Odds of Winning. One drawing will be held on or around September 21, 2010, for the following awards: One (1) Grand Prize consisting of a Celestron NexStar 8SE Telescope (retail value $1,199). One (1) First Prize consisting of a Celestron SkyMaster 15x70 Binoculars (retail value $89.95). One (1) Second Prize consisting of a Celestron TravelScope (retail value $79.95). One (1) Third Prize consisting of a Celestron FirstScope 50th Anniversary Edition (retail value $70). Ten (10) Fourth Prizes consisting of a subscription to *Astronomy* magazine (retail value $42.95 each). Cash equivalents of merchandise will not be awarded. Substituting prizes is not allowed. Any applicable federal, state, and/or local taxes are the responsibility of the winner. Odds of winning depend on the number of entries received. Total circulation for *Astronomy* magazine is 112,233. Sweepstakes void in Quebec and void where prohibited.

4. Validation and Acceptance. Winners in the *Astronomy* and Celestron 2010 Summer Sweepstakes will be selected in a random drawing. Canadian prize awards subject to skill test requirement. By entering the sweepstakes, participants agree to be bound by these official rules and all decisions of Kalmbach Publishing Company. Sweepstakes entries void if not legible, not completed in full, not obtained legitimately, or if forged, photocopied, mechanically reproduced, late or tampered with. The potential winners may have to sign and return an Affidavit of Eligibility, publicity release and Release of Liability within fourteen (14) days of notification. In the event of non-compliance, alternate winners will be randomly drawn. No responsibility is assumed for lost, stolen, misdirected or late entries or notifications. All sweepstakes entries become the property of Kalmbach Publishing Co. and will not be returned.

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Webtalk

Summer observing targets for small telescopes

In this video, *Astronomy* Senior Editor Michael E. Bakich showcases the objects you can see this summer using a 4-inch or smaller telescope. Highlights include the Hercules Cluster, the Ring Nebula, the Lagoon Nebula, and more.

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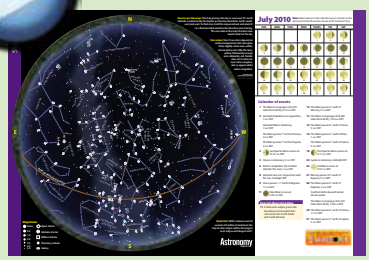

Video: How to use a star chart

Senior Editor Richard Talcott helps you navigate the night sky using *Astronomy* magazine's pullout star chart — located in the center of each monthly issue.

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Strange Universe

by Bob Berman

Odd patterns, dead oxen

Are all the planets numerically linked with Earth?

We humans readily perceive patterns. We see rabbits in summer clouds and even a face on the Moon. For astronomers, however, designs are most trusted when they're mathematical. Some, like Kepler's laws, changed our science. Others are simply startling. Pythagoras was so spellbound when he realized the square of any right triangle's sides add up to the square of its hypotenuse, he purportedly sacrificed 100 oxen to honor the gods. Such a stunning relationship between nature and numbers had to be divine, he reasoned. Fortunately, the animal rights office was closed that day.

Maybe you don't love math. But just this once let's look at some freakish links between numbers and planets. Most famous is the strange sequence first mentioned by Scottish astronomer David Gregory in 1702 and later published by Johann Titius and then Johann Bode. Take the pattern: 0, 3, 6, 12, 24, 48, 96, 192 — which keeps doubling. Add 4 to each. Insert a decimal point, and you get: 0.4, 0.7, 1.0, 1.6, 2.8, 5.2, 10.0, and 19.6. Weirdly enough, this accurately expresses each planet's distance from the Sun. Here's the progression, which was soon called Bode's law, along with the actual planet distances in Earth-Sun units, or AUs: Mercury 0.4 (actual is 0.39), Venus 0.7 (actual 0.72), Earth 1.0 (1.0), Mars 1.6 (1.52), empty 2.8, Jupiter 5.2 (5.2), and Saturn 10.0 (9.54).

When Bode popularized this in 1768, nothing matched the "2.8" and no planet lay beyond Saturn's "10." But William Herschel soon found Uranus, and, wham, it nicely fit the next Bode number, 19.6 (actual distance: 19.19). Then came Ceres in 1801. First considered a planet, it nailed that empty 2.8 gap to perfection. The whole thing worked.

Trouble was, no physics can explain this neat way the planets are ordered. It's math without science. When Neptune was found in 1846 and didn't match, the pattern was quietly dismissed as just a wild coincidence.

But is it? These days some astronomers think orbital resonances — the way planets interfere with others — may be responsible for Bode's law. So it may be valid after all.

The sky is riddled with math oddities. The Moon is 400 times smaller than the Sun but also 400 times closer, making them appear the same size. And both spin at virtually the same rate. Just coincidences, right?

For astronomers, designs are most trusted when they're mathematical.

Recently, a British reader named Roger Elliott sent me his interesting observation that all planets have a bizarre numerical connection with Earth, and with one-eighth of a circle, which is 45° — half a right angle. Check it out:

During precisely 1 Earth year, each planet performs a certain number of spins on its axis, and then rotates a further additional angle that is always very nearly a multiple of 45°.

For example, in exactly 1 Earth year, slow-turning Venus spins once and then a further angle of 181.08°, which is just 1.08° from 4 × 45°. During the same Earth year, Jupiter rotates 883 times and then an additional angle of 88.8°, just 1.2° from 90° — a multiple of 45°. In a year, Saturn makes 822 complete spins and then turns another 227.14°, just 2.14° from a multiple of 45° (45° × 5 = 225°).

Astoundingly, this 45° business continues with each planet's orbital period as well. During Mercury's "year" of 87.969 days, Earth revolves in its solar orbit 86.7°, which misses a half-right-angle multiple (2 × 45°) by just 3.3°. During Mars' orbit of 686.98 days, Earth makes one revolution and then moves an additional 317.09°, which is just 2.09° more than a 45° multiple (45° × 7 = 315°). On it goes. Every planet with no exception, even Pluto and the three largest asteroids. None deviates by more than a few degrees from a 45° multiple. The odds against this being mere chance are thousands to one. To masochistically check all the data, go to Roger's web site, created in sync with this article: www.halfrightanglerule.com.

Why should Earth be linked with every other planet's rotation and revolution? And why half right angles? Indeed, this is the first time this idea has been published. Because it lacks any scientific justification, should we dismiss it as coincidence, a la Bode? Is it simply an odd result of statistical cherry-picking? Or, rather, does it fascinatingly hint at some undiscovered celestial mechanics, perhaps involving phase-locking or particle effects?

There are other bewildering patterns, too, like the bizarre giant hexagon found at Saturn's north pole, which researchers are finally beginning to understand. These days we seem teased — by elegantly simple math in odd places.

It's good Pythagoras is no longer with us. No animal would be safe.

Browse the "Strange Universe" archive at www.Astronomy.com/Berman.

Contact me about my strange universe by visiting **skymanbob.com.**

Observing Basics

by Glenn Chaple

A historical perspective

Classic guides penned a century ago can greatly enhance your astronomy library.

"What more gracious day's progress in beauty could there be than to travel with the eye from the cheerful hepaticas dotting the soft ground ... to the round, white, silent blossoms of the dogwood fringing the late April woods and thence, when evening falls, to the bright yet gentle light of Arcturus in the sky, announcing the end of the purple twilight."

Those eloquent words, penned more than a century ago by Martha Evans Martin in her book *The Friendly Stars* (1909), are typical of the lyrical style that defined the astronomical writings of the time. Using the written word the way an artist might apply paint to the canvas, authors like Martin, Garrett P. Serviss, and William Tyler Olcott penned classic guides that captivated the reader with vivid descriptions of the wonder and beauty of the night sky. Consider the way Serviss, in his 1908 *Astronomy with the Naked Eye*, describes the late-spring demise of the constellation Orion:

"Orion, declining to the west in a spring evening when the snows are gone, the trees have begun to feel the sap, and the misty atmosphere is drowsy with the aroma of the awakening earth, is a dethroned monarch."

These guides also provide insight into the state of amateur astronomy in the late 19th and early 20th centuries. They differ from present-day versions not only in writing style, but also in their lists of featured deep-sky objects. A century ago, double and multiple stars dominated these lists at the expense of clusters, nebulae, and galaxies. It was the era of the long-focus refractor; double stars were a natural target for such a high-power, narrow-field instrument. The bias is evident in Olcott's *In Starland with a Three-Inch Telescope* (1909). Highlighting the deep-sky objects present in Ursa Major, he devotes three sentences to the double star Mizar while describing M81 and M82 simply as "two fine nebulae separated by only half a degree." Olcott is less kind to the "great nebula" in Andromeda (M31), dismissing it as "a disappointing object in an ordinary telescope."

Classic books like *The Friendly Stars*, *Astronomy with an Opera-Glass*, and *Astronomy with the Naked Eye* are great additions to any astronomy library. Michael E. Bakich library

Not only do M31, M81, and M82 get bad press, but Olcott also seems to demote them from extragalactic status. Back then, people regarded fuzzy, unresolved blobs of light as gaseous accumulations like the Orion Nebula, ensconced within the bounds of the Milky Way. They generally believed nebulae with spiral structure were swirling gas clouds in the process of condensing into planetary systems. Not until the 1920s, when astronomers were at last able to resolve its stars and determine an extragalactic distance, did these nebulae become galaxies.

In perusing the observing lists, you'll find that some deep-sky objects seem to be placed in the wrong constellations. Before a revision by the International Astronomical Union in 1930 to update and straighten them, boundaries between constellations wove randomly in and out.

While some things a century ago were different, others remain the same. Nowadays, we fret about the light pollution that degrades skies in urban areas. If only we could go back a hundred years to a time when the night sky was free of light pollution. Think again! In *The Amateur Astronomer*, written by Gideon Riegler in 1910, the author issues the following lament:

"One other consideration that will most prejudicially affect astronomical observation at night-time in the city, is the so-called 'city glare,' the reflection of light from the innumerable street lamps and other artificial sources of illumination."

There is a special shelf in my astronomy library devoted to classic guides from the past. Some of my favorites beyond the ones I've already mentioned include: *The Bedford Catalogue* (1844), by Adm. William H. Smyth; *Celestial Objects for Common Telescopes* (1859), Rev. T. W. Webb; *A Field Book of the Stars* (1929), Olcott; *Astronomy with an Opera-Glass* (1888), Serviss; and *Pleasures of the Telescope* (1901), Serviss.

Why not add some of these classics to your astronomy library? Check out swap tables at astronomy conventions. Reprints often appear on the shelves of book stores. Or because the copyright has lapsed on many of these books, you can download them for free at http://books.google.com or www.archives.com. Take the opportunity to go back to a time when celestial wonders were admired and contemplated, rather than analyzed and dissected.

Browse the "Observing Basics" archive at www.Astronomy.com/Chaple.

Secret Sky

by Stephen James O'Meara

O'Neill's illusion?

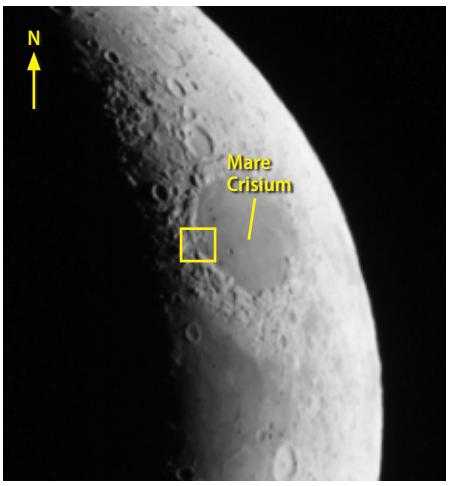
The search continues for a feature on the Moon that may or may not be there.

Sometimes the line between reality and fiction blurs. Take, for instance, O'Neill's Bridge, a sometime feature located on the Moon. Arthur C. Clarke introduced readers to it in his 1961 science-fiction novel, *A Fall of Moondust*.

In this futuristic story, drama unfolds as the lunar tourist cruiser *Selene* sinks 50 feet (15 meters) into a sea of moondust after the collapse of an underground cavern the ship traveled over. While the passengers and crew await rescue, Mr. Radley (a New Zealand accountant who believes "saucerites" are after him) admits that he came to the Moon disguised as a tourist to find evidence of O'Neill's Bridge.

Radley recounts how an American astronomer named O'Neill discovered an artificial bridge on the rim of Mare Crisium. "Other astronomers, of course, laughed at him," Radley scoffed, "but less prejudiced ones confirmed the existence of the bridge. Within a few years, however, it had vanished. Obviously, our interest had alarmed the saucer people, and they had dismantled it."

While Clarke's novel is fiction, Radley's account of O'Neill's discovery is, for the most part, accurate. In fact, observers today still have fun using their telescopes to sail the western shores of Mare Crisium in search of the mysterious lunar feature that once haunted the minds of astronomers on both sides of the Atlantic Ocean.



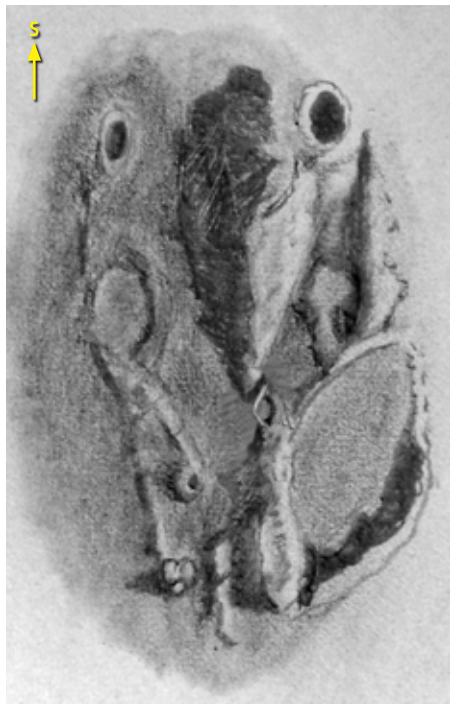
O'Neill's Bridge supposedly bridges a small gap between two lunar headlands on the western edge of Mare Crisium. Although it's almost certainly an illusion, the idea that such an enormous object could appear so unexpectedly is a captivating one. Stephen James O'Meara

Mind games

On the morning of July 29, 1953, John J. O'Neill, science editor for the *New York Herald Tribune*, turned his 4-inch refractor to the Moon and began surveying Mare Crisium's western rim at 90x. A low Sun lit up the region's lofty peaks, which stood like islands in a black sea of shadow. But O'Neill's attention turned to a small fan of light that breached the surrounding darkness. It emerged from a tiny gap between the tips of two lunar headlands: Promontorium Olivium and Promontorium Lavinium. Curious, he increased the magnification to 125x, then to 250x.

At that higher power, something remarkable snapped into view: a "gigantic natural bridge" arcing over the gap like one of those stone marvels of the American Southwest. Spanning about 12 miles (19 kilometers) in length, however, O'Neill's Bridge would have dwarfed any of Earth's natural arches, the most prominent of them spanning less than 300 feet (92 meters).

After 90 minutes of observing, O'Neill became convinced of his discovery. After alerting other observers, confirmations soon began to trickle in. The most promising came from Hugh Percy Wilkins, director of the British Astronomical Association's (BAA) Lunar Section, who used a 15-inch Newtonian reflector to verify the arch's existence. Wilkins saw not only the arch with sunlight streaming beneath it, but also the bridge's shadow on the surrounding lunar terrain. It was, beyond a shadow of a doubt (excuse the pun), real.



Stephen James O'Meara

Looking through his 5-inch refractor at 330x on the evening of January 4, 2010 (lunar colongitude of 124°), the author saw a scene much like this drawing. Note how in this view the shadows are just near enough to the "arch" to make it appear not only as if sunlight is streaming through it, but also enough to create the illusion that the arch's shadow is projected onto the lunar surface. But if you look carefully, you'll realize that the shadow (if this were a natural arch) is falling in the direction of the Sun, not away from it!

Utter lunacy

In a British Broadcasting Corporation radio interview on December 23, 1953, Wilkins shared his observations with listeners. "Now this is a real bridge," he

Find O'Neill's Bridge

You'll want to look when the colongitude of the sun is 127°, which happens on the following dates.

July 29, 2010, 7:40 UT
August 27, 2010, 18:55 UT
September 26, 2010, 06:55 UT
October 25, 2010, 19:50 UT
November 24, 2010, 09:40 UT
December 24, 2010, 00:05 UT

explained. "Its span is about 20 miles from one side to the other, and it's probably at least 5,000 feet or so from the surface beneath."

Asked whether he was "quite certain" that he didn't somehow mistake the bridge for some other object, Wilkins replied, "Oh, no, there's no mistake at all. It's been confirmed by other observers. It looks artificial."

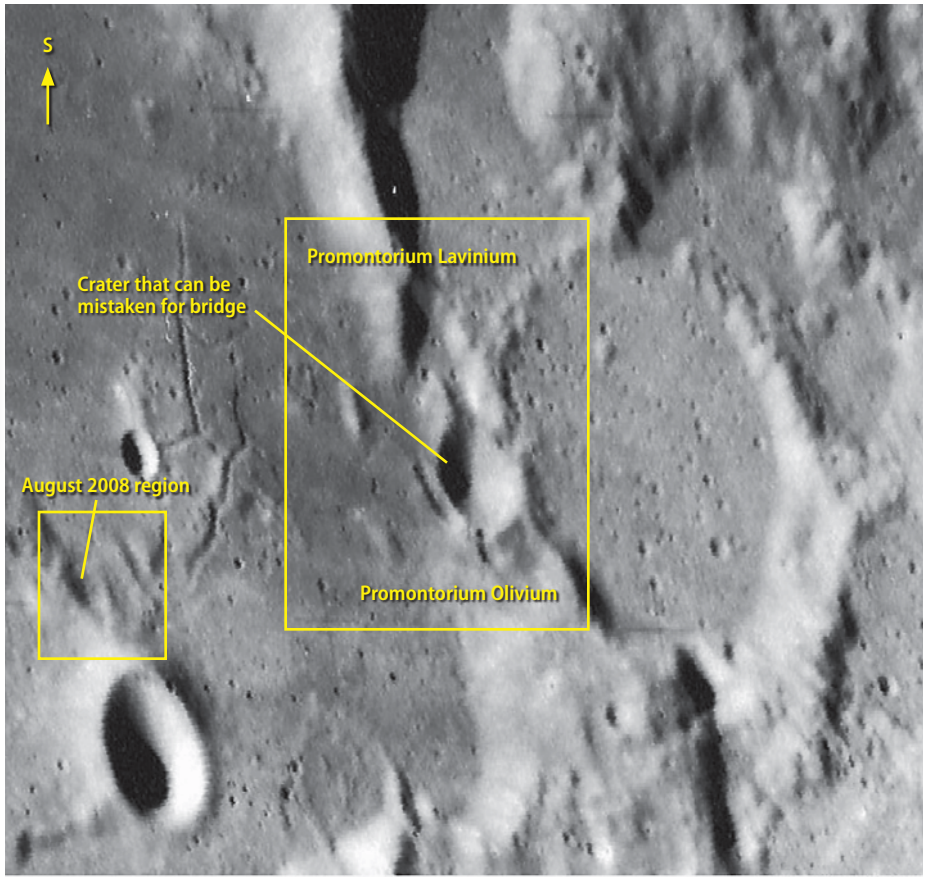
When asked to clarify "artificial," he replied, "Well, it looks almost like an engineering job."

A sensational story based on Wilkins' interview ran in newspapers across America, raising the ire of skeptical colleagues on two continents. Wilkins retorted that the media had taken his views out of context. But the damage had already been done. Indeed, the story of O'Neill's Bridge soon captured the attention of UFO buffs.

In his 1955 book, *The Flying Saucer Conspiracy*, Major Donald E. Keyhoe contributed a slightly different version of O'Neill's discovery description: "The huge structure appeared sharply in outline, an unbelievable engineering marvel apparently erected in weeks, perhaps in days." Keyhoe added that "not even O'Neill dared to tell the whole story," noting that in his report to the Association of Lunar and Planetary Observers, O'Neill called it "a gigantic natural bridge." Keyhoe continues, "But the sudden appearance of such a structure by an act of nature was absolutely impossible, as many privately admitted."

The previous year, at a 1954 BAA meeting, Wilkins tried to extinguish some of the fires he had started by sharing a more recent observation. While using the 60-inch reflector at Mount Wilson Observatory in Southern California, Wilkins found O'Neill's Bridge illusory, a trick of light and shadow. Ironically, he did spy a much smaller hole 1.5 miles (2.4 km) across in nearby Promontorium Olivium.

Writing about this latter feature in his 1963 book *A Survey of the Moon*, Patrick Moore says, "This may be so: but at best it is a tiny natural feature of no interest or importance whatsoever."



This Apollo 17 image shows the region of O'Neill's Bridge and the crater that the author (among others) believes might be the cause of the illusion (on the right). Unfortunately, the direction of sunlight is opposite the necessary direction to see the "bridge." To prove how easy it is for the interplay of light and shadow to fool us, the author searched the region for other "lunar bridges." Using a 4-inch refractor and 315x, he found a smaller possibility (on the left) August 19, 2008 (lunar colongitude of 124.3°). It appears to be a lunar crater fragment or sections of a lunar ridge. NASA

To the scopes!

If you'd like to search for O'Neill's Bridge, the best time to look is when the Sun is near a lunar colongitude of 127°. What you see will depend not only on how close Promontorium Olivium and Promontorium Lavinium are to the lunar terminator (the dividing line between night and day on the Moon), but also on lunar libration effects — the small rocking (east-west) and nodding (north-south) motions of the Moon over time.

Of course, no one knows exactly what O'Neill saw because the "bridge" doesn't exist. But since the summer of 2008, I've enjoyed surveying the area under different lighting conditions. Although I've never seen the actual gap bridged, a crater on Promontorium Olivium close to the gap can resemble a natural arch under the right lighting conditions, when seen with south up. Remember, significant changes in the shape and appearance of lunar surface features can occur in as little as a half-hour of watching, so be patient and have fun.

(Editor's note: Owing to a computer glitch, O'Meara lost all Astronomy *reader e-mails from January and February 2010. If you sent him an e-mail during that time, especially one relating to an observation or sky phenomena, please resend the material to someara@interpac.net.)*

Browse the "Secret Sky" archive at www.Astronomy.com/OMeara.

Evening Stars

by David H. Levy

An observing trip in time

Gazing at the skies takes on a new level of wonder when you consider your place in history.

Thin white clouds crisscrossed the deep-blue sky late in the afternoon of Friday, January 8. As the Sun dipped below the southwestern horizon, I had the eerie feeling that comes from repeating a nearly 50-year-old observing session.

On September 1, 1960, I set up my scope, turned it toward Jupiter, and "discovered" the great planet's four bright moons: Io, Europa, Ganymede, and Callisto. That was observing session number 3, only my third time under the stars. In January 2010, during session 15,706, I wanted to rediscover those moons, not just for the benefit of my wife, Wendee, and me, but also to honor what Galileo had done precisely 400 years earlier.

My first telescope, Echo, is now half a century old, and its mirror hangs loosely in its cardboard tube. Even though I pointed it directly at Jupiter, I didn't see an image at first because the off-kilter mirror reflected Jupiter toward the walls of the tube and not my eye. But after some jiggling, the black view through the eyepiece transformed into a deep-blue sky with a beautiful white world in the middle. Some distant clouds prevented me from seeing any companions at first; but as they cleared away, three of Jupiter's moons dimly sprung into view (two hanging above the planet, one below).

Reading Galileo's *Sidereus Nuncius* ("Sidereal Messenger") allows us to relive his initial observations of these moons. Although he first noticed them January 7, Galileo did not express surprise until the next day: "But returning to the same investigation on January eighth — led by what, I do not know — I found a very different arrangement," he wrote. "I began to concern myself with the question [of] how Jupiter could be east of all these stars when on the previous day it had been west of two of them. … Hence it was with great interest that I awaited the next night."

Jupiter and its four largest moons always make for a stunning sight, whether 400 years ago or today. This composite image is not to scale, but shows the moons in their relative positions (from top to bottom: Io, Europa, Ganymede, and Callisto). NASA/JPL

Galileo's great discovery, I like to think, actually did not take place on the 7th when he noticed some extra "stars" hanging near Jupiter, but on the 8th when he witnessed these same objects still swarming around the planet. And so, on January 8, 2010, Wendee and I celebrated that auspicious event 400 years after it happened.

Galileo took careful notes of his observations, but we have no idea what led him to look at Jupiter again on January eighth; even he didn't know what led him to repeat the observation. On one of the most important days in the history of civilization, we do not know what Galileo had for breakfast, or even if he mentioned the observations to his astronomy students at the University of Padua. But we can be pretty certain that he soon would, because his mind was by that time completely focused on the exhilaration of his discovery.

About 400 years before this issue of *Astronomy* landed in your mailbox, Galileo's publication of *Sidereus Nuncius* appeared in the middle of March 1610, announcing (among other things) the discovery of Jupiter's moons. By that time, Galileo's words had set all of Europe abuzz, and multitudes tripped over each other trying to buy a telescope so they could see the moons for themselves.

Accordingly, I suggest that right now — tonight — you observe with the simplest telescope you can find. It can be something as small as the popular Galileoscope or an old reflector that's been gathering dust in a closet. Jupiter is now in the morning sky (turn to "The Sky this Month" for details on spotting it), but Saturn most definitely remains visible at night, and with the rings starting to angle toward us again, it makes for an astounding sight. You'll find, like the Europeans did 400 years ago, and like I did 50 years ago, that even a thousand pictures can't come close to seeing, with your own eyes, the real beauty of the stars.

Browse the "Evening Stars" archive at www.Astronomy.com/Levy.

NEXT MONTH
in the August issue

Rob Ratkowski

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Enlightening dark matter Astronomers have begun using the growth rates of black holes to determine the density of nearby dark matter, according to a paper in the May *MNRAS*.

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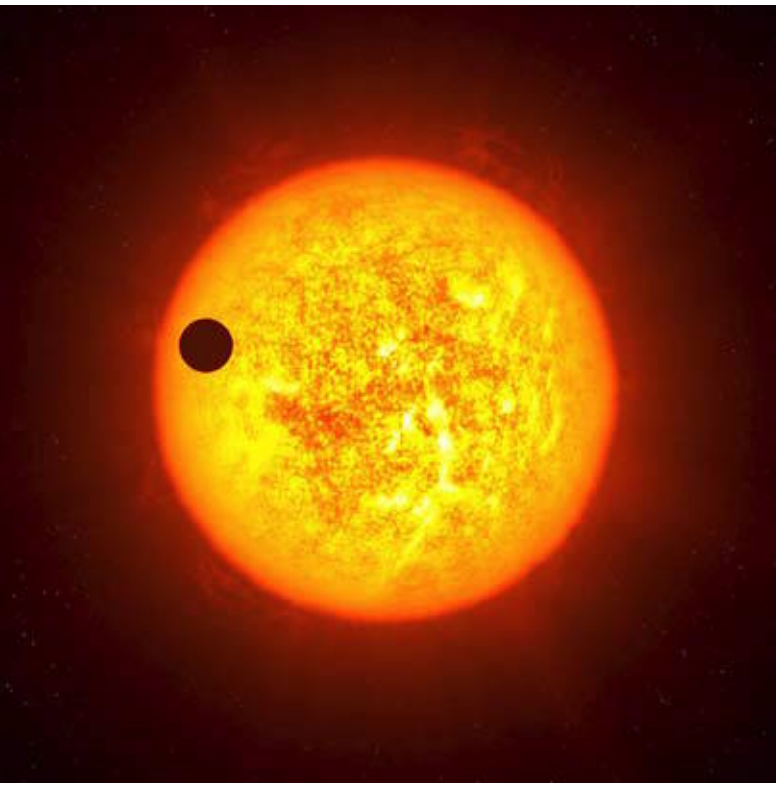


Luke-warm Jupiter. CoRoT-9b, shown here transiting its star in an artist's impression, is the first known temperate exoplanet scientists can study in detail. ESO/L. Calçada

CoRoT discovers new temperate exoplanet

The COnvection ROtation and planetary Transits (CoRoT) space telescope has discovered the first temperate, Jupiter-like exoplanet scientists can probe in detail, according to a March 18 paper in *Nature*. Named CoRoT-9b, the new planet orbits a star cooler than our Sun some 1,500 light-years away in the constellation Serpens Cauda. "CoRoT-9b is the first exoplanet that really does resemble planets in our solar system," says lead author Hans Deeg of the Instituto de Astrofísica de Canarias.

CoRoT-9b transits (passes in front of) its star about every 95 days, allowing astronomers to study changes in the star's light to analyze the planet's properties. "This is a normal, temperate exoplanet just like dozens we already know, but this is the first whose properties we can study in depth," says Claire Moutou, part of the international team of 60 astronomers that made the discovery.

About the size of Jupiter with an orbit similar to Mercury's, CoRoT-9b is mostly hydrogen and helium, with up to 20 Earth masses worth of heavier elements, perhaps including rock and water. Scientists expect its temperature to range from about –4° to 320° Fahrenheit (–20° to 160° Celsius), setting it apart from "hot Jupiter" exoplanets, comparable to Jupiter's size but much closer to their stars than Mercury is to the Sun. — **BILL ANDREWS**

20 Found: 90 percent of galaxies

20 Mars Express sweeps past Phobos

21 How to make a supernova even bigger

22 Research begins in earnest at the LHC

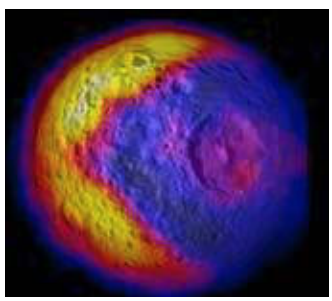
22 Jupiter's helium rain might account for little neon

Mimas appears hot in all the wrong places

On February 13, NASA's Cassini spacecraft made its closest pass yet by Saturn's moon Mimas. Planetary scientists used the opportunity to map the icy moon's temperature and found a strange pattern: The temperature appears to spike early in the morning.

"Although other moons usually grab the spotlight, it turns out Mimas is more bizarre than we thought it was," says Cassini project scientist Linda Spilker of NASA's Jet Propulsion Laboratory. "It has certainly given us some new puzzles."

Cassini scientists expected temperatures to vary smoothly, with the peak in early afternoon near the equator. Instead, early morning is the warmest time. Mimas is still cold — the hot spots reach –294° Fahrenheit (92 kelvin) while the rest of the moon holds at –320° F (77 K). A small warm spot exists around the big crater Herschel. Scientists suspect the temperatures reveal differences in surface texture. — **RICHARD TALCOTT**



NASA/JPL/GSFC/SwRI/SSI

Pac-Man moon. Temperatures vary oddly on Mimas, with the warmest areas (yellow) occurring near dawn and cool regions (blue) elsewhere.

Answering an age-old question

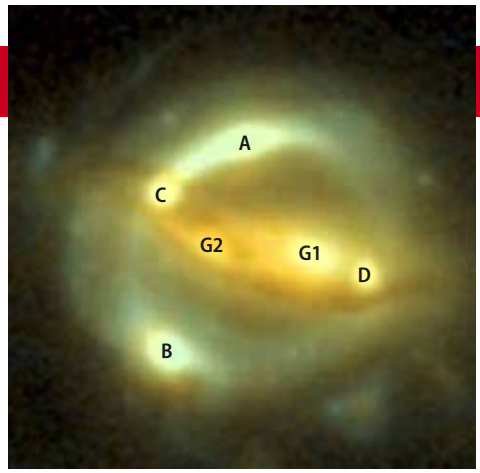
How old is the universe, and how fast is it expanding? In the past decade, researchers have made amazing progress in pinning down answers. Now, an international team of astronomers has used an independent method to explore these questions. The new numbers confirm the previous values.

The new results place the universe's age at 13.75 billion years (to within 170 million years) and the expansion rate at about 70.6 kilometers per second per megaparsec. These numbers fall in the same range and have similar accuracies as those coming from the Hubble Space Telescope and the Wilkinson Microwave Anisotropy Probe.

The team examined B1608+656, a massive galaxy pair in Draco. This system acts as a gravitational lens, distorting light from an active galaxy that lies farther away. The distant galaxy's light travels different paths through the lens, creating multiple images of the active galaxy.

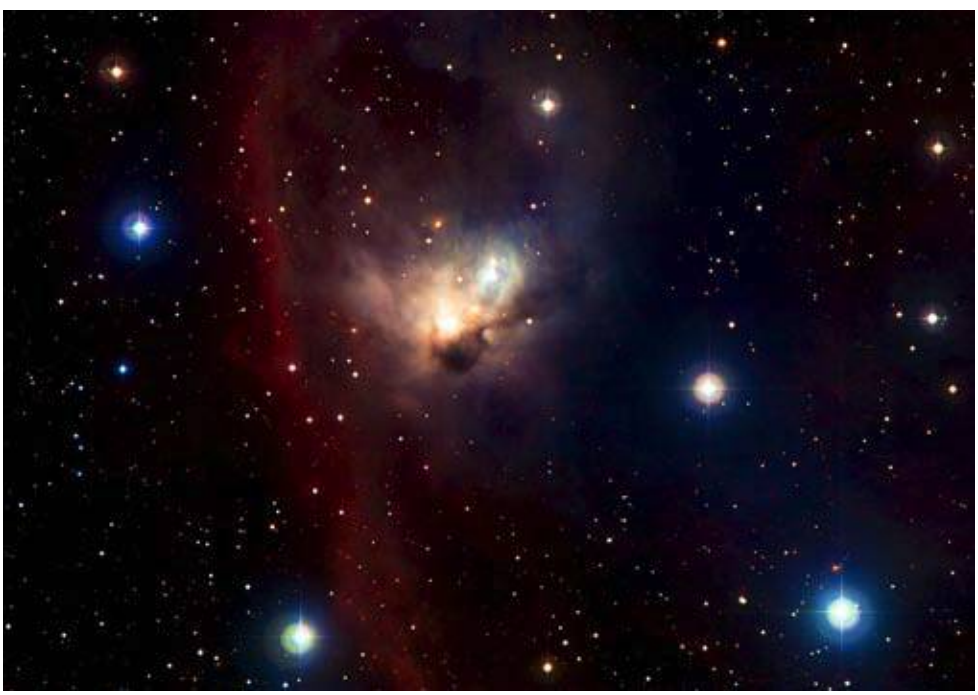
"There are four copies of the source, which appear as a ring of light around the lens," says team leader Sherry Suyu of the University of Bonn, Germany. As the active galaxy's brightness fluctuates, the four images vary at different times.

By measuring the ebb and flow of light along the four distinct paths, the astronomers inferred the overall scale of the universe and details of its expansion. The new results, reported in the March 1 issue of *The Astrophysical Journal*, also confirm dark energy's strength. This antigravity-like force accelerates cosmic expansion. — **R. T.**



NASA/ESA/Sherry Suyu (University of Bonn) et al.

Looking glass. The massive gravitational lens cataloged as B1608+656 consists of two galaxies (G1 and G2). The lens splits the light of an active background galaxy into four separate images (A, B, C, and D). Observations of these images show the universe to be 13.75 billion years old.



Star-forming nebula dangles off Orion's Belt

Newborn nebula. Just a few degrees away from Orion's Belt lies the faint nebula NGC 1788, shown here in a detailed European Southern Observatory image released March 3. The older stars closer to Orion (on the left) have gathered opposite the younger ones, suggesting that the constellation's hot, massive stars created a wave of star formation that's spreading outward through the nebula. The region's stars average only about a million years of age, making them all extremely young. — B. A. ESO

STOPPING THE STARS

Astronomers discovered evidence that a "catastrophic event," powerful explosions occurring every second, caused an ancient galaxy to stop its star formation, according to a March *MNRAS* paper.

BINARY BONANZA

A March 10 *The Astrophysical Journal Letters* paper describes the discovery of the smallest-known and fastest-orbiting binary system, found in HM Cancri.

SQUEAKY-CLEAN QUASAR

Scientists have spotted the second-known dust-free quasar, likely implying it's in the early stages of development. Details appear in the March 18 *Nature*.

GALACTIC GROWTH SPURT

A *Nature* paper published online March 21 describes a remote galaxy that forms stars at rates much greater than modern galaxies, suggesting such "growth spurts" are common to young galaxies.

TRUE LAVA

NASA scientists announced March 4 at the 41st Lunar and Planetary Science Conference that lava — not water — might have carved some of the channels on Mars' surface.

BIRTHING BIG STARS

A paper in the March 10 *The Astrophysical Journal* may have solved the riddle of how the biggest stars form: Models suggest nascent radiation heats surrounding matter instead of scattering it.

QUAKE-INDUCED QUASAR

A *Science* paper published online March 25 suggests quasars (the energy- and light-producing centers of some galaxies) may form as the result of galactic collisions.

JAMES WEBB GOES AHEAD

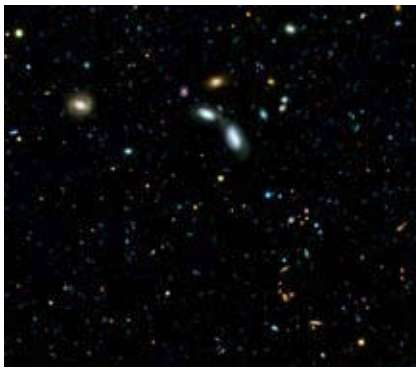
NASA announced March 18 that it had sent a working copy of the James Webb Space Telescope's camera to begin testing, bringing the next-generation telescope a little closer to completion.

BLOWN AWAY

A March *Geophysical Research Letters* study detailed how the solar wind plays a major role in depleting Mars' atmosphere, blowing it into space.

SCHOOL SPACE SCIENCE

NASA announced March 25 that it had chosen the four high school teams whose experiments would fly aboard a NASA weather balloon launch in May.



Lookin' GOODS. Some of the faintest galaxies ever seen are visible in this composite image of the GOODS-South field, including the 90 percent or so that had previously gone undiscovered. ESO/M. Hayes

Found: 90 percent of galaxies

For years, astronomers suspected that they were only seeing a small fraction of the light coming from the distant universe. A March 25 paper in *Nature* describes how to make the hidden light visible, revealing the 90 percent of previously unknown galaxies. (Dark matter, which doesn't emit light at all, is a completely unrelated phenomenon.)

Scientists typically look for the "fingerprint" of light called the Lyman-alpha line but knew that such light could remain trapped within its home galaxy, never to reach Earth. Instead, a new extremely deep survey using the European Southern Observatory's Very Large Telescope looked for a different wavelength of light characterized by the Hydrogen-alpha line. This light is less easily absorbed by interstellar gas, allowing it to extend past where Lyman-alpha light would be stopped.

"Astronomers always knew they were missing some fraction of the galaxies in Lyman-alpha surveys," says lead author Matthew Hayes of l'Université de Genève, "but for the first time we now have a measurement. The number of missed galaxies is substantial." Hayes and his team searched a well-known area of the sky called the GOODS-South field, looking specifically at galaxies with a redshift of 2.2, meaning their light had traveled for about 10 billion years.

"Now that we know how much light we've been missing," says co-author Miguel Mas-Hesse, "we can start to create far more accurate representations of the cosmos, understanding better how quickly stars have formed at different times." — **B. A.**

Mars Express sweeps past Phobos

The European Space Agency's Mars Express spacecraft has orbited the Red Planet more than 8,000 times since it arrived in December 2003, but few orbits held the excitement of those in late February and March 2010. Twelve times during the month, Mars Express flew close by Mars' moon Phobos. The diminutive moon, which measures 17 by 14 by 12 miles (27 by 22 by 19 kilometers), is still significantly larger than Mars' only other natural satellite, Deimos.

Mars Express orbits the Red Planet in a highly elliptical polar orbit that brings it close to Phobos every 5 months. But the March series was special because it brought the probe closer to Phobos than any spacecraft had ever come. In fact, Mars Express is the only spacecraft currently at Mars whose path lies far enough from the planet to provide close-up views of the moon.

Groovy Phobos. Mars Express snapped this image March 7 during one of its closest flybys of Phobos. Linear grooves and lots of craters highlight this detailed view, which has a resolution of about 14 feet (4.4 meters) per pixel. ESA/DLR/FU Berlin (G. Neukum)

ESA/DLR/FU Berlin (G. Neukum)

Spud moon. Potato-shaped Phobos is Mars' biggest moon, although its longest axis spans only 17 miles (27 km). The object's largest crater, called Stickney, lies on the moon's upper left limb. This image has a resolution of about 30 feet (9 meters) per pixel.

During the first few flybys, the probe's radar instrument took the central role. It shot radar beams at cratered Phobos and recorded the echoes. Mission scientists hoped the radar would reflect off structures beneath the moon's surface, revealing some detail about what lies inside. It likely will take the radar team a year or more to fully analyze the results.

The March 3 flyby was the closest of all. Mars Express skimmed just 42 miles (67 km) above the moon's surface. For this encounter, mission controllers sent a radio signal from Earth to the spacecraft and then listened to the signal returned by the probe. The moon's gravity caused subtle variations in the signal that gave scientists their best look yet at the moon's internal structure.

Phobos has a density so low that it can't be solid the whole way through. Planetary scientists think it is a "rubble pile" composed of large and small blocks wedged together with large voids in the regions where they don't fit together easily. Overall, Phobos must be 25 to 35 percent porous. The new data should show density variations and perhaps even reveal voids throughout the moon's interior.

During the subsequent flybys, the spacecraft's high-resolution camera took over. The images captured Phobos' pockmarked surface and the long grooves splayed across it.

Among the specific targets were areas Russia is considering as possible landing sites for its Phobos-Grunt (meaning Phobos Soil) mission. Russia plans to send the spacecraft to Phobos in late 2011 or early 2012. It will land on the moon, collect a soil sample, and return it to Earth for analysis. — **R. T.**

When galaxies collide

A March 25 *Science* Express paper posits that the giant black holes in the centers of galaxies grow from galactic collisions.

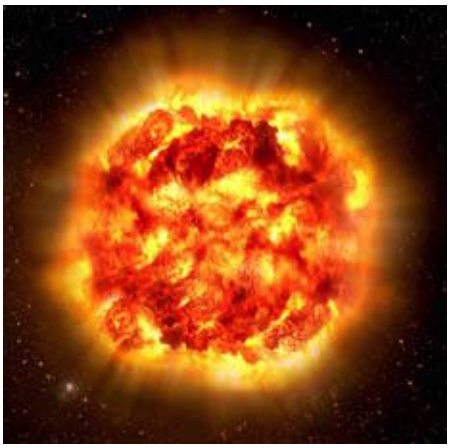
How to make a supernova even bigger

In the past 7 years, astronomers have stumbled across four supernovae that appeared brighter than theory suggests is possible. Now a team of researchers has confirmed that one of these rare blasts, designated SN 2007if, arose in a system whose mass exceeded the theoretical limit.

Type Ia supernovae occur when a white dwarf star explodes. Until recently, astronomers thought white dwarfs could not exceed the so-called Chandrasekhar limit — a critical mass equal to 1.4 solar masses. When a white dwarf reaches this limit, typically by accreting material from a companion star, the dwarf explodes. And, because the explosions all come from similar progenitor stars, they all appear equally bright.

Richard Scalzo of Yale University led a team that studied the abnormally bright SN 2007if in unprecedented detail. Using telescopes in Chile, Hawaii, and California, the researchers measured the individual masses of the progenitor star, the shell of debris ejected by the explosion, and the surrounding envelope of pre-existing material. The team will report their results in an upcoming issue of *The Astrophysical Journal*.

The astronomers found that the progenitor weighed in at 2.1 solar masses, well above the Chandrasekhar limit. How did SN 2007if get around nature's rules? Scalzo thinks this explosion (and the three similar ones) occurred when two white dwarfs in a binary system merged with each other. In this scenario, neither would have exceeded the mass limit.



Super supernova. A type Ia supernova occurs when a white dwarf star reaches an upper-mass limit and explodes, as seen in this artist's concept. But new results show a handful of supernovae exceed this limit and create even more powerful explosions. ESO

The results have more than theoretical interest because cosmologists use type Ia supernovae to measure the rate of cosmic expansion. "Supernovae are being used to make statements about the fate of the universe and our theory of gravity," says Scalzo. "If our understanding of supernovae changes, it could significantly impact our theories and predictions." — **R. T.**

Planck captures cold dust

Cool crowd. Although its main research focus is the universe's microwave background radiation, the Planck mission snapped this image of a dusty region in our galaxy. It's actually a composite of pictures taken in two of Planck's nine frequencies. This image spans one-thirteenth of the sky in far-infrared radiation. The pink horizontal line is the Milky Way's disk, and the tendrils of cold dust are areas where stars might form in the future. Planck is a European mission that launched May 2009. — **LIZ KRUESI** ESA and the HFI Consortium, IRAS

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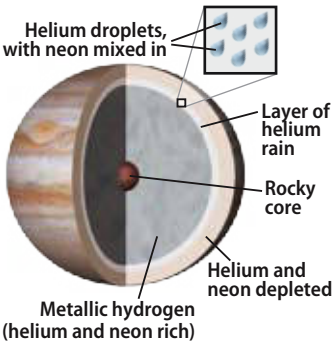
Back in time A new Hubble treasury project will soon provide an unparalleled view of the formation of galaxies over the first third of cosmic time, a team of international scientists announced March 15.


Helium droplets, with neon mixed in
Layer of helium rain
Rocky core
Helium and neon depleted
Metallic hydrogen (helium and neon rich)

Drops of Jupiter. New simulations of Jupiter's atmosphere predict that helium raindrops combine with neon on their way down, helping to explain their oddly low concentrations. *Astronomy:* Roen Kelly, after Burkhard/Militzer

Jupiter's helium rain might account for little neon

New predictions by scientists at the University of California, Berkeley, suggest that helium condenses into droplets on Jupiter and falls like rain, taking with it much of the outer atmosphere's neon. The theory is detailed in a paper in the March 26 *Physical Review Letters*.

Astronomers had known since 1995's Galileo probe entered the jovian atmosphere that helium and especially neon weren't as abundant as predicted. Hugh Wilson and Burkhard Militzer, the paper's authors, ran simulations showing that the only way to remove neon would be to have it drip out with helium because the two elements mix easily.

"Helium condenses initially as a mist in [Jupiter's upper atmosphere], like a cloud, and as the droplets get larger, they fall toward the deeper interior," says Wilson. "Neon dissolves in the helium and falls with it. So our study links the observed missing neon in the atmosphere to another proposed process, helium rain."

Wilson adds that this prediction can help fine-tune models of Jupiter's interior, along with the structure of other bodies, including extrasolar planets. — **B. A.**

Research begins in earnest at the LHC

After nearly 20 years of construction and a few false starts, the Large Hadron Collider (LHC) at the European Organization for Nuclear Research (CERN) began colliding protons at energies of 7 trillion electron volts (TeV) March 30. A new record for man-made particle accelerators, the two 3.5 TeV beams will continue for 2 years before the LHC shuts down for planned upgrades and maintenance, preparing it for eventual 14 TeV collisions.

"A lot of people have waited a long time for this moment," says CERN Director General Rolf Heuer, "but their patience and dedication is starting to pay dividends." At such high energies, the LHC has a good chance of making significant discoveries about the structure and makeup of the universe.

By smashing bits of matter at incredibly high speeds, CERN scientists hope to re-create conditions just moments after the Big Bang, when more exotic particles still existed. The LHC's data could help explain just what dark matter is, indicate the presence of extra dimensions, and even find the elusive Higgs boson particle. — **B. A.**

BRIEFCASE

Cosmic matter flows, but why?

In late 2008, NASA's Alexander Kashlinsky led a team that announced that galaxy clusters seem to be moving toward one spot on the sky. New research incorporating 2 more years of data was published in the March 20 issue of *The Astrophysical Journal Letters*. The study indicates that this mysterious "dark flow" of galaxy clusters extends twice as far as originally reported. — L. K.

Killer electrons explained

The European Space Agency announced March 12 that its Cluster mission has determined that both very low frequency waves (3 to 30 kilohertz) and ultra-low frequency waves (0.001 to 1 hertz) can cause "killer electrons." These energetic particles can penetrate the shielding on Earth-orbiting satellites, creating microscopic lightning that can damage the satellite. — B. A.

Alan Rogers wins

The Queen Victoria Museum in Tasmania, Australia, announced March 1 that Alan Rogers won the 2010 Grote Reber Medal. The award recognizes outstanding and innovative contributions to radio astronomy. Rogers, a research affiliate at MIT's Haystack Observatory, made his mark by developing several techniques used in very long baseline interferometry. — R. T.

25 years ago in *Astronomy*

July 1985

In the July 1985 issue of *Astronomy*, astronomer Edward C. Olson analyzed the possibilities of discovering "Intelligent Life in Space" using the Drake Equation, which quantifies how many intelligent, communicating life-forms exist elsewhere in the universe.

After examining the variables and assigning them values, Olson concluded grimly: "[If] the communicative lifetime of a civilization is roughly a million years, then we are the only technological civilization in two Milky Way galaxies. If [it's] 100 years, then we are unique among 20,000 such galaxies."

"Our 'pessimistic' conclusion is still theoretical and admittedly quite speculative," Olson added. "Enthusiasts may find means to get around this conclusion." Given that our recent look at Drake's equation in the April 2010 issue concluded our galaxy alone should house 10,000 civilizations, it would appear they did.

July 2000

10 years ago in *Astronomy*

The July 2000 issue of *Astronomy* featured 18 pages devoted to Mars, "a special issue without even trying," as then Editor Bonnie Bilyeu Gordon wrote.

"Red Planet Renaissance" by William K. Hartmann explored scientists' renewed fascination with Mars. Thanks to recent discoveries suggesting active volcanoes and underground rivers, Mars began resembling the lively planet envisioned 200 years prior.

An excerpt from Joel Achenbach's *Captured By Aliens* followed Robert Zubrin's efforts to create the Mars Society, dedicated to settling the Red Planet. "We were supposed to be on Mars already," Achenbach wrote of Zubrin's frustration.

And "Missing the Mark," by then Senior Editor Rex Graham detailed NASA's failed missions to Mars, and its (ultimately successful) future missions. "The NASA that is supposedly doing more science with less money," Graham wrote, "is overdue for its current reality check." — **B. A.**

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How we'll explore Pluto

Now halfway to its goal, NASA's New Horizons spacecraft promises to reveal frigid Pluto during an extraordinary 9-month encounter in 2015. **by Richard Talcott**

For a spacecraft that spends most of its life sleeping, NASA's New Horizons probe is in the midst of an eventful year. Speeding toward a 2015 rendezvous with distant Pluto, the spacecraft passes the halfway point of its journey in 2010. And it does so not once, but twice.

On February 25, New Horizons was 1.484 billion miles (2.388 billion kilometers) from where Earth was on the day of its launch, January 19, 2006. And it was the same distance from where Pluto will be when the spacecraft makes its closest approach July 14, 2015.

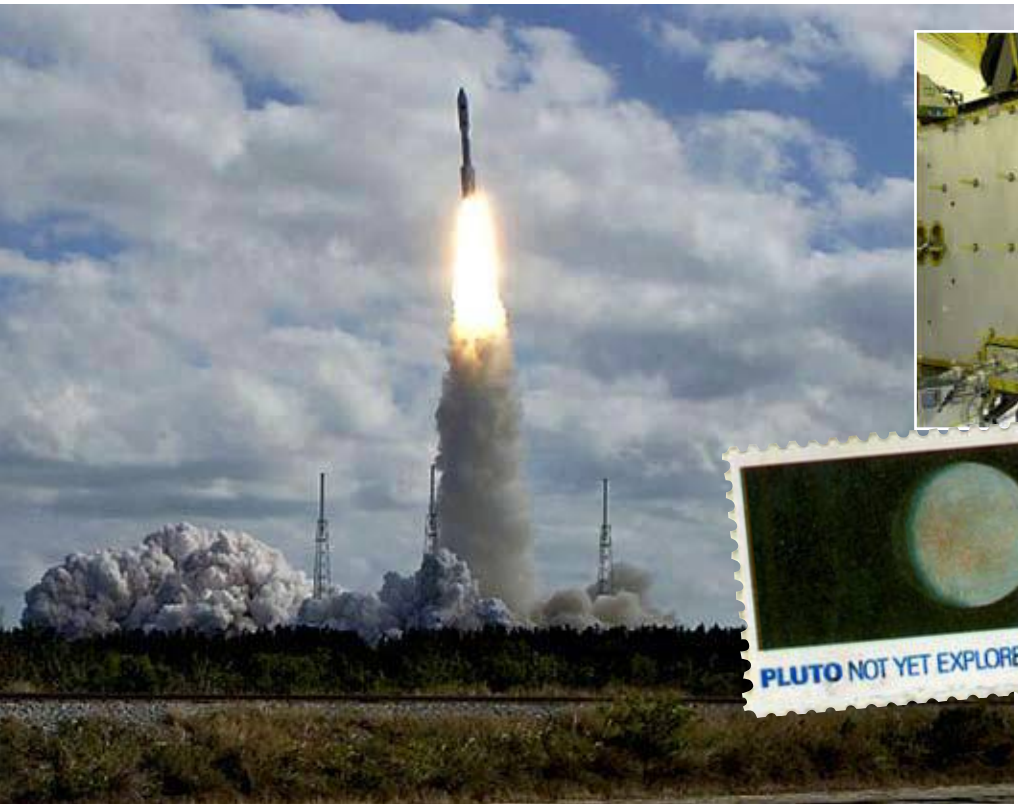
But moving away from the Sun's gravity is hard work. Our star's powerful pull slows the probe's outward push, so it has yet to travel half the flight time to Pluto. It will reach that milestone October 16.

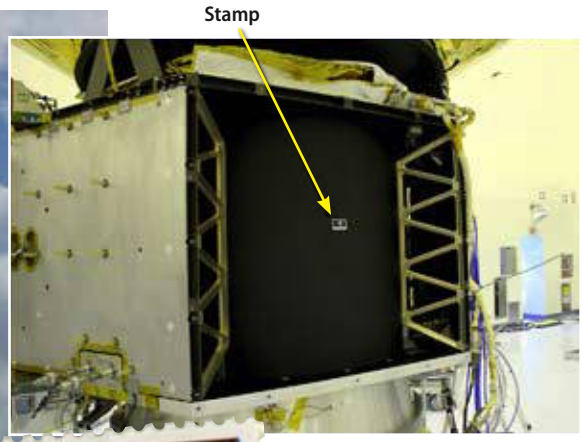
The celebrations onboard have been muted, however. New Horizons hibernates much of the time. About once a week, it stirs enough to send a signal back to Earth, letting scientists on the ground know all is well. And this summer, from late May to early July, mission controllers will awaken the probe for a series of important tests.

During this 50-day active period, the New Horizons team will check out all the spacecraft systems and the seven science instruments. Scientists will take the opportunity to perform a little "cruise science," examining the interplanetary environment and taking some distant images of Uranus and Neptune. Mission controllers also will fire the spacecraft's rockets to make a small trajectory correction, the first for New Horizons since September 2007. And, perhaps most importantly, the team will run through its first full-length dress rehearsal of the Pluto close-encounter sequence.

Richard Talcott *is an* Astronomy *senior editor and author of* Teach Yourself Visually Astronomy *(Wiley Publishing, 2008).*

New Horizons skims a few thousand miles above Pluto's frozen surface in July 2015. The dwarf planet's large moon, Charon, lies in the background. Ron Miller for *Astronomy*





New Horizons rides atop an Atlas V booster (far left) as it departs Florida's east coast January 19, 2006. NASA

Return to sender? Ron Miller, who illustrated this article's opening scene, created a Pluto stamp (left) in 1991 as part of a series he did for the U.S. Postal Service. One of those stamps (above, seen affixed to the spacecraft) is now on its way to Pluto. Left: Ron Miller; above: NASA/Alan Stern

A short and not-so-winding road

The apparent lethargy of New Horizons at the moment is just a mask, of course. The spacecraft is in a race against time to reach Pluto. The planet's thin atmosphere, formed as the distant Sun warms the surface and the ices there turn directly to gas, may soon disappear. Pluto reached the closest point to the Sun in its 248-year orbit in 1989. As the planet retreats farther into the solar system, it cools off, and the tenuous atmosphere eventually will freeze out.

To try to beat the atmosphere's inevitable demise, New Horizons was built for speed. First, it's lightweight — at launch, the spacecraft weighed just 1,054 pounds (478 kilograms), about half the weight of a compact car. And that included all the propellant for the mission.

Second, New Horizons rocketed into space faster than any other spacecraft. The Atlas V first stage, Centaur second stage, and STAR 48B solid rocket third stage launched the probe at 35,800 mph (57,600 km/h).

New Horizons crossed the gap from Earth to Jupiter in 13 months, reaching the giant planet February 28, 2007. That's lightning quick compared with the travel time to the outer solar system for some previous spacecraft. The Galileo probe took more than 6 years to reach Jupiter, and it needed two gravity assists from Earth and one from Venus. Cassini required more than 3 years along with two gravity assists from Venus and one from Earth before it reached Jupiter, and an additional 3.5 years to rendezvous with its target, Saturn.

Eye on Jupiter

As New Horizons shot past Jupiter, it turned its suite of instruments on the giant planet and its four big moons. The encounter provided the first close-up look at the jovian system since the demise of the Galileo probe in 2003. New Horizons took the most-detailed images ever of Jupiter's Little Red Spot (aka Red Spot, Jr.) and measured its supersonic winds. The spot had been a white oval cloud until 2005, when its color and character changed.

New Horizons also took the clearest photos ever of Jupiter's faint ring system. The onboard cameras discovered three bright clumps of fine dust particles in the rings. Scientists estimate that these closely spaced clumps were born within a few months of the spacecraft's flyby.

Pluto on the horizon

In the 80 years since Clyde Tombaugh discovered Pluto, scientists have learned much about this world. In 5 years, the floodgates will open.

1930
Lowell Observatory astronomer Clyde Tombaugh discovers Pluto.

1965
Researchers C. J. Cohen and E. C. Hubbard discover that Pluto lies in a 3:2 orbital resonance with Neptune.

1976
University of Hawaii scientist Dale Cruikshank and colleagues discover methane ice on Pluto.

1978
U.S. Naval Observatory astronomer James Christy discovers Pluto's big moon, Charon. The revelation allows scientists to accurately measure Pluto's mass for the first time.

1985
Mutual occultations between Pluto and Charon start. Observations subsequently yield the first accurate diameters for the two objects.

1987
Astronomers Marc Buie (University of Hawaii) and Robert Marcialis (University of Arizona) lead teams that discover water ice on Charon.

Jupiter's übervolcanic moon Io also came under New Horizons' watchful eye. The probe's LORRI high-resolution imager captured the Tvashtar volcano in mid-eruption, returning the most-detailed photos ever of a volcanic plume on Io. (The plume soared 200 miles [320 km] above the moon's pockmarked surface.) In addition, New Horizons discovered at least two new eruptions and more than 20 geological changes on Io since the Galileo probe's observations.

As exciting as the science at Jupiter turned out to be, it took a back seat to two more important mission requirements. First, the New Horizons team learned how to fly its spacecraft through a demanding encounter with a planet — information that will pay dividends when the spacecraft reaches Pluto and executes its primary mission.

And second, the flyby allowed New Horizons to steal an infinitesimal amount of Jupiter's orbital energy. This gravitational slingshot boosted the spacecraft's speed by 9,000 mph (15,000 km/h) and set it on an even faster track to Pluto. Without the Jupiter gravity assist, New Horizons would have taken at least 3 years longer to reach its target.

Pluto and its three moons don't look like much more than points of light from Earth, even to the sharp eye of the Hubble Space Telescope. Hal Weaver (JHUAPL)/Alan Stern (SwRI)/NASA/ESA

A pair of crescent moons orbiting Jupiter posed for New Horizons in 2007. Io and its massive Tvashtar plume appears at top with icy Europa to its lower left. NASA/JHUAPL/SwRI

Onward and outward

When the pioneering probe reaches Pluto, what will it encounter? A planet, a dwarf planet, or a Kuiper Belt object? If you listen to New Horizons' principal investigator S. Alan Stern, the spacecraft will find all three. Stern and a large number of other planetary scientists take issue with the International Astronomical Union (IAU), which decided in 2006 to demote Pluto from full planet status. This despite the fact that only about 5 percent of IAU members were present to vote on the new definition of a planet.

"The IAU embarrassed itself" with its decision, says Stern, who also uses words like "stupid" and "idiotic" to describe the IAU's action. Stern plays a mean game of "what if." What if you moved Pluto into Venus' orbit? The IAU would have to call Pluto a planet. And what if you moved Earth out to Pluto's orbit? You would have to say goodbye to Earth's planetary status. In fact, if you moved massive Jupiter deep into the Kuiper Belt — the region beyond Neptune occupied by Pluto, perhaps 100,000 icy dwarf worlds, and billions of comets — even our solar system's largest planet would be a planet no more.

New Horizons' cameras delivered sharp details of Jupiter's cloud tops when the spacecraft passed by in 2007. Expect equally good images when the probe reaches Pluto in 2015. NASA/JHUAPL/SwRI

Stern and many others prefer to divide the planets into three groups. Mercury, Venus, Earth, and Mars are the terrestrial planets, relatively small rocky worlds that cling close to the Sun's warmth. Jupiter, Saturn, Uranus, and Neptune form the giant planets, freakishly large worlds that dominate the solar system's middle region.

And then there's the third group: the dwarf planets. This coterie includes Pluto and Charon, their even-larger Kuiper Belt

1988
MIT scientist Jim Elliot and colleagues discover Pluto's thin atmosphere when it occults a background star.

1992
University of Hawaii astronomer Toby Owen and colleagues discover nitrogen and carbon monoxide ices on Pluto.

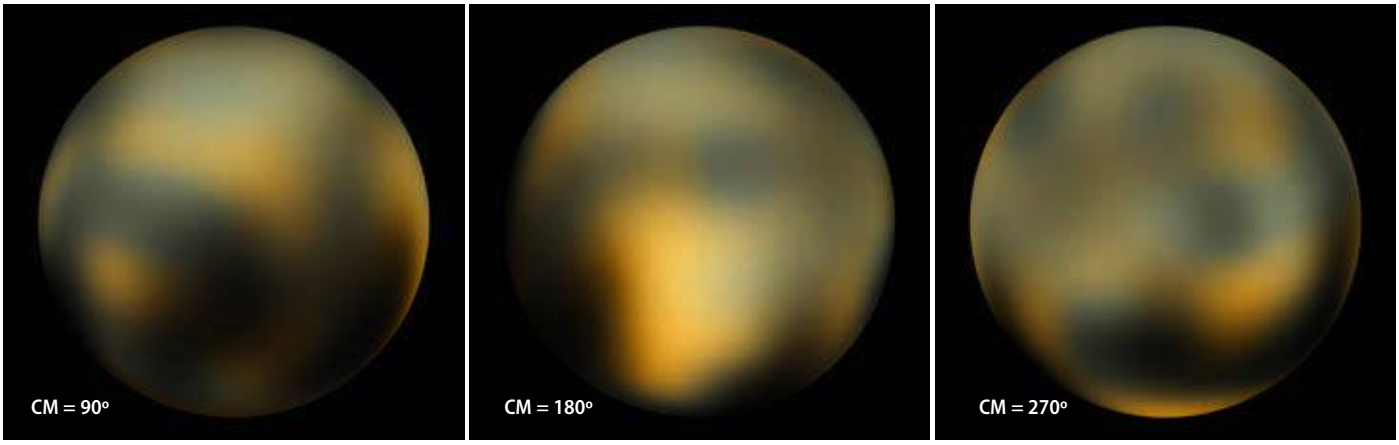
2005
Hal Weaver (Johns Hopkins University) and S. Alan Stern (Southwest Research Institute) lead a team that discovers Pluto's two small moons, Nix and Hydra.

2006
New Horizons launches from Cape Canaveral, Florida.

2006
The International Astronomical Union decides that Pluto is no longer a planet.

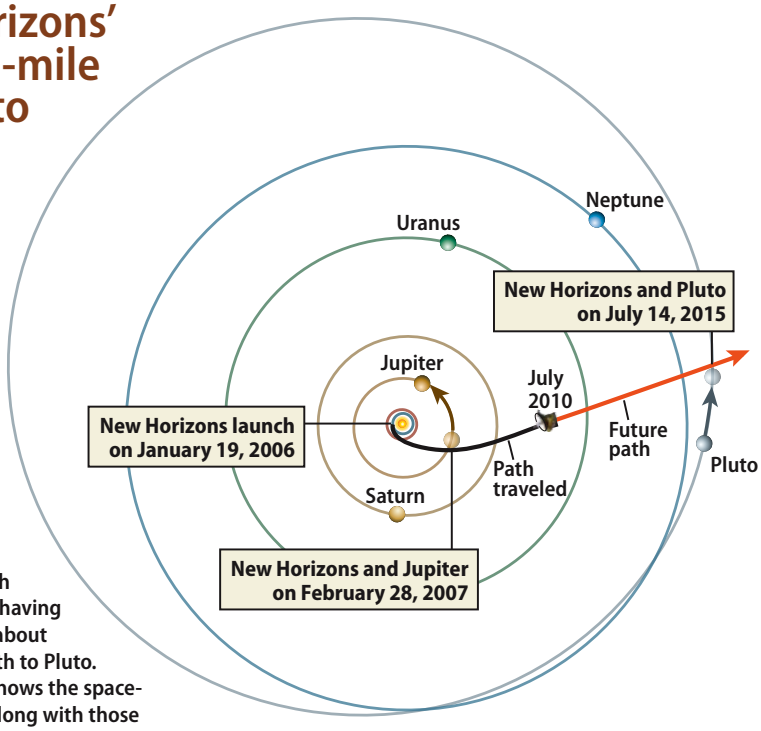
2007
New Horizons flies within 1.4 million miles (2.3 million km) of Jupiter, receiving a gravity assist that sends it toward Pluto.

2015
New Horizons arrives at Pluto, flying within 6,200 miles (10,000 km) of the distant world.



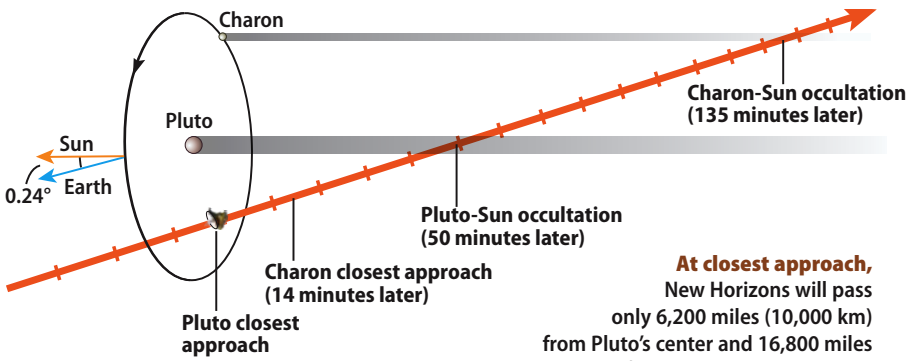
Pluto's mottled terrain contains white, dark-orange, and charcoal-black patches. These three views, which were created from Hubble images, depict different hemispheres. (Each view gives the central meridian [CM].) They will remain the best views of Pluto until New Horizons arrives. NASA/ESA/Marc Buie (SwRI)

New Horizons' 3-billion-mile voyage to Pluto



New Horizons is speeding through the solar system, having already traveled about halfway from Earth to Pluto. This illustration shows the spacecraft's position (along with those of the planets) in early July 2010. *Astronomy*: Roen Kelly

Positions of outer solar system planets on July 1, 2010, except where noted



Spacecraft trajectory shows tick marks every 10 minutes

At closest approach, New Horizons will pass only 6,200 miles (10,000 km) from Pluto's center and 16,800 miles (27,000 km) from Charon's center. It will zip through the system at nearly 9 miles per second (14 km/sec). *Astronomy*: Roen Kelly

cousin Eris, and a host of other distant icy worlds. In this emerging view, Pluto qualifies as a planet, as a dwarf planet, and as the brightest Kuiper Belt object in the heavens. And New Horizons will be the first spacecraft to explore these latter two categories of solar system residents.

Initial reconnaissance

But first it has to get there. The spacecraft crossed Saturn's orbit in June 2008. It will cross Uranus' orbit in March 2011 and Neptune's in August 2014. Not long thereafter, mission controllers will awaken the probe for its Pluto encounter.

Although closest approach to Pluto (and Charon) arrives July 14, 2015, New Horizons will start viewing the system 5 months prior. At first, the objects will appear as little more than bright dots. But that changes rapidly as the spacecraft continues at breakneck speed.

Starting about 3 months out, at a distance of some 60 million miles (100 million km), the cameras and spectrometers will make their first global maps of Pluto and Charon. Ten weeks from closest approach, the images will exceed the best from the Hubble Space Telescope.

Four weeks before closest approach, the increasingly detailed maps will be sharp enough to reveal any changes that take place over a Pluto day. (Pluto and Charon rotate in lockstep; both have days that last 6.4 Earth days.) New snowfalls or other weather events should become obvious at this stage.

But the best part of the journey promises to be the 9-day close encounter. The ground team already has plotted this phase of the Pluto reconnaissance in

exquisite detail. The delicate trade-offs between the different instruments demand precise planning so that New Horizons can meet all the mission objectives. Earlier this year, the team began working on the approach and departure legs of the entire 9-month encounter.

During the month before closest approach, New Horizons will map the entire surfaces of Pluto and Charon as well as those of the smaller moons Nix and Hydra. This even includes the permanently shadowed regions in Pluto's polar regions. Charon casts nearly 20 percent as much light on Pluto as a Full Moon does on Earth, and that feeble light will be enough illumination for the probe's sensitive cameras.

A frozen wonderland

At closest approach, New Horizons will skim approximately 6,200 miles (10,000 km) from Pluto's center and 16,800 miles (27,000 km) from Charon's center. And it will be zipping along at nearly 9 miles per second (14 km/sec), so it will cover one Pluto diameter (1,485 miles [2,390 km]) in about 3 minutes.

The cameras should deliver incredible detail. "If New Horizons were to fly the same distance from Earth and we imaged a college campus," says Stern, "we could count the number of buildings and determine their shapes."

Pluto's surface hovers at a temperature of about –387° Fahrenheit (–233° Celsius) and is covered with nitrogen-rich ices and at least one patch of carbon monoxide frost. When frozen, nitrogen forms transparent crystals several inches across, so the landscape could be dazzlingly beautiful. Surprisingly, Charon's surface has a different character, with water ice its main component.

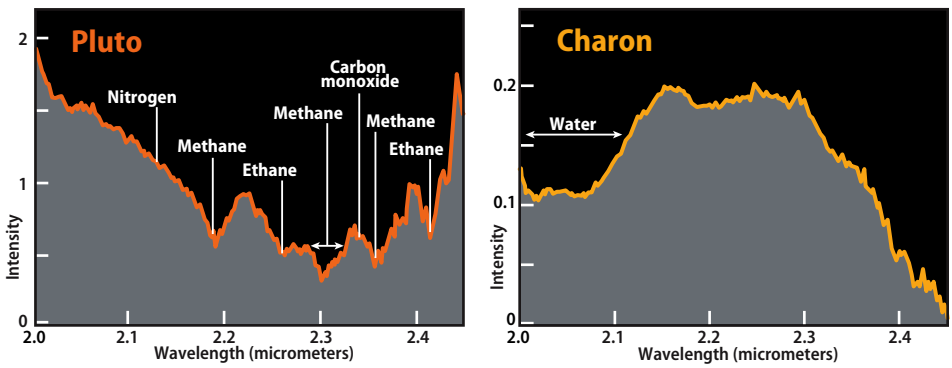
Although New Horizons will study Pluto's atmosphere before and during closest approach, some of the most sensitive measurements will come shortly afterward. That's when the probe enters Pluto's shadow and looks back at sunlight filtering through the air.

Likewise, radio waves from the craft have to pass through this air on their way to Earth. These observations should reveal the atmosphere's composition and structure and how its temperature changes with altitude.

This assumes, of course, that the atmosphere is still there. Astronomers observed it early this year when Pluto passed in front of a star. But as Pluto moves away from the Sun and grows colder, the atmosphere eventually will freeze onto the surface. "It will collapse — we just don't know when," says Stern. He hopes it happens after 2015. Still, Stern says, New Horizons could detect Pluto's atmosphere even if its pressure were one-thousandth of what it is today.

After leaving Pluto behind, New Horizons will forge ahead. It likely will encounter one or two other Kuiper Belt objects on its sojourn — searches for the best candidates will begin this summer.

Meanwhile, scientists will pore over the observations of Pluto and its moons, trying to glean the last iota of knowledge they can. What New Horizons will turn up is anyone's guess — it's why we're going in the first place.



Spectra of Pluto and Charon tell a tale of two surfaces. Pluto shows ices rich in nitrogen, carbon monoxide, and hydrocarbons, while water ice dominates Charon. *Astronomy*: Roen Kelly, after Subaru Telescope/NAOJ

Read more about Pluto, Charon, and their Kuiper Belt brethren at www.Astronomy.com/toc.

Seven ways to explore a planet

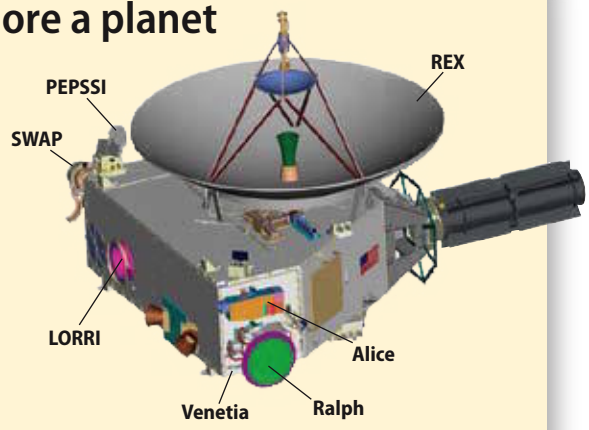
To make the first close-up observations of the Pluto system, the New Horizons' team chose seven science instruments. Ralph, a combination camera and spectrometer, observes in the visible and infrared parts of the spectrum and will map the surface compositions and temperatures of Pluto and its moons.

Alice operates at shorter wavelengths, in the ultraviolet, and will analyze the structure and composition of Pluto's atmosphere. (The names Ralph and Alice are an homage to the main characters in the 1950s TV show *The Honeymooners*.)

The LOng Range Reconnaissance Imager (LORRI) has the highest resolution of any New Horizons camera. It will provide the sharpest close-up pictures of Pluto and its companions as well as detailed views from farther away.

Two instruments — the Solar Wind Around Pluto (SWAP) and the Pluto Energetic Particle Spectrometer Science Investigation (PEPSSI) — will study the plasma environment around Pluto. They will probe ions escaping from Pluto's atmosphere and determine whether the planet has a magnetic field.

The Radio science EXperiment (REX) will measure the composition and temperature of Pluto's atmosphere and yield precise values for the masses of Pluto and Charon. The seventh instrument, the Venetia Burney Student Dust Counter (Venetia), is studying the density of dust across the outer solar system for the first time. — *R. T.*



Cameras, spectrometers, and a dust counter make up the payload for the New Horizons spacecraft. *Astronomy*: Roen Kelly

HUBBLE'S top 5 science discoveries

From dark energy to exoplanets to black holes, the Hubble Space Telescope helps astronomers understand some of the biggest mysteries of the universe.

by Ray Villard

The universe was a different looking place 20 years ago as the Hubble Space Telescope was tucked inside the space shuttle *Discovery*'s cargo bay and readied for launch.

The most powerful optical telescopes on Earth could see only halfway across the universe. Even estimates for the age of the universe disagreed by a big margin. Supermassive black holes were only suspected to be the powerhouses behind a rare zoo of energetic phenomena seen at great distances. We didn't know if any planets orbited other stars.

Hubble, the first major optical observatory in space, gave us a rapid-fire series of discoveries and breakthroughs after its deployment into low Earth orbit April 25, 1990. The instrument quickly became the trailblazer of a golden age of space astronomy.

Today, Hubble's 2.4-meter mirror seems puny compared to the giant 8- to 10-meter giant monolithic and segmented mirrors at major mountaintop observatories. But the pristine view from above Earth's atmosphere makes a huge difference. Hubble consistently has a 10 times sharper view than ground-based telescopes. True, adaptive optics has narrowed this margin, but Hubble still yields razor-sharp images across a wide field of view. Add to that its unparalleled ability to see high-contrast objects because there is no sky background.

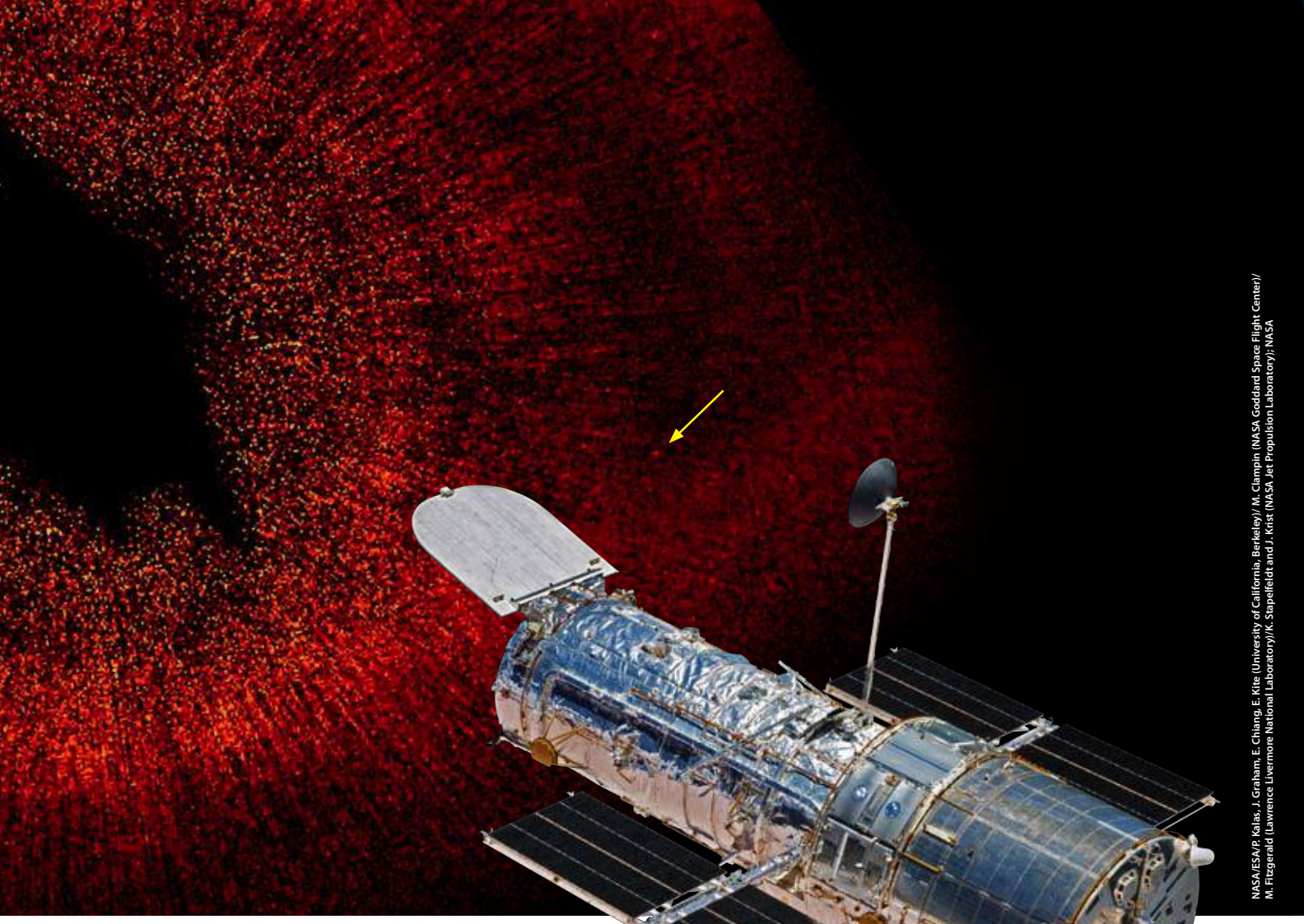
Hubble's optically stable view allows revisited targets a guaranteed same acuity and repeatability of data quality. Hubble can see across a wide swath of the spectrum of light, from ultraviolet all the way to near-infrared, giving it truly "panchromatic" vision.

Armed with these powerful capabilities, Hubble has made remarkable discoveries across astronomy, rewritten textbooks, been the source of more than 7,000 science papers, and reawakened the public to the wonders of the universe.

Hubble has made remarkable discoveries across astronomy, rewritten textbooks, been the source of more than 7,000 science papers, and reawakened the public to the wonders of the universe.

Here's a look at Hubble's top five top scientific achievements:

Ray Villard *is news director for the Space Telescope Science Institute in Baltimore, Maryland, which oversees Hubble's operations.*



NASA/ESA/P. Kalas, J. Graham, E. Chiang, E. Kite (University of California, Berkeley)/ M. Clampin (NASA Goddard Space Flight Center)/ M. Fitzgerald (Lawrence Livermore National Laboratory)/K. Stapelfeldt and J. Krist (NASA Jet Propulsion Laboratory); NASA

The Hubble Space Telescope, at right, has made several important scientific discoveries, such as detecting the first visible light from an extrasolar planet, Fomalhaut b (arrow).

1 Galaxies evolved from smaller structures

In 1990, astronomers could detect only normal galaxies out to a redshift of 0.7 at best, corresponding to a distance of 7 billion light-years in a universe thought to be twice that big. For years, conjecture and theoretical models hypothesized how galaxies must evolve if the universe was a cooling fireball left over from the Big Bang. Ground-based observations couldn't establish which of several competing theories best described how galaxies formed and evolved in the early universe.

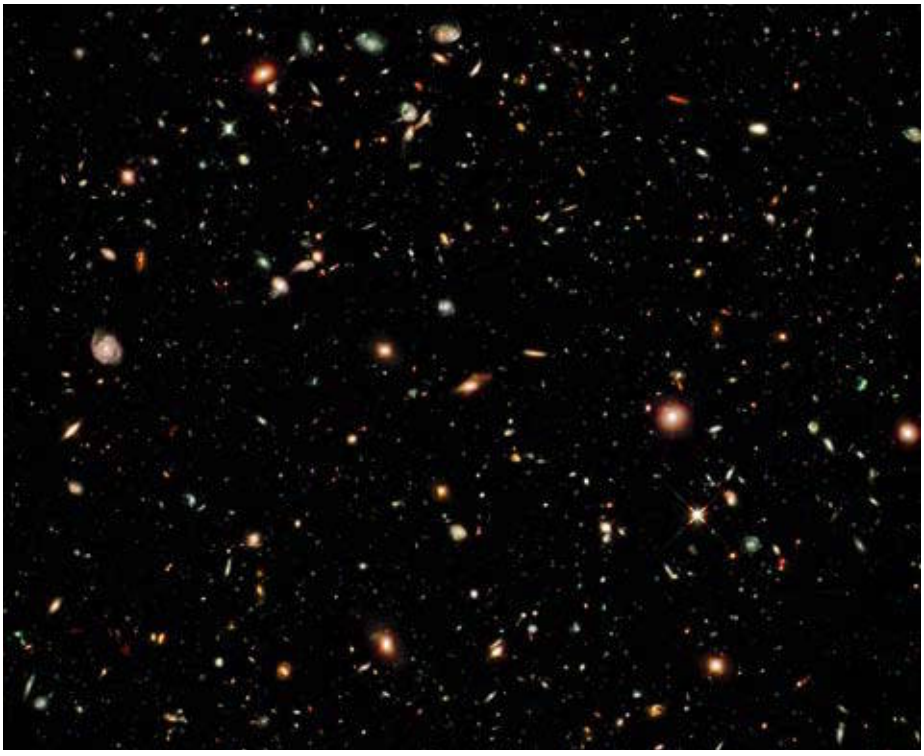
In 1985, a committee of top astronomers planning to use Hubble concluded that devoting 200 orbits to a "deep exposure" of the universe would be fruitless. Extrapolating from the known universe of the time, they assumed that the geometry of space at great distances would spread out the light of normal galaxies, making them too diffuse for Hubble to see.

Fortunately, nature cooperated. Early Hubble observations taken even before its optical repair in 1993 showed galaxies at a then record-breaking redshift of 1.5 (more than 9 billion light-years). They appeared more compact and therefore concentrated their light into a smaller area — making them detectable to Hubble. Astronomers noted many strange-shaped "pathological" galaxies dubbed "tadpoles" and "train wrecks." Even normal galaxies had bright knots of star birth that were easily visible.

These findings encouraged the director of the Space Telescope Science Institute (STScI) at that time, Robert Williams, to devote a large chunk of his director's observing time to carrying out a million-second exposure to make the deepest-ever view of the universe. It reached an unprecedented 28th magnitude.

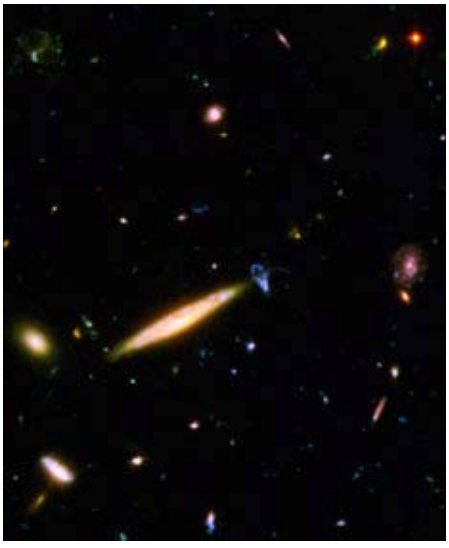
With the installation of Hubble's Advanced Camera for Surveys in 2002, the next STScI director, Steve Beckwith, pushed further to make the Hubble Ultra Deep Field (HUDF). This ensured that astronomers weren't accidentally seeing only compact objects and missing larger galaxies. The HUDF reached 29th magnitude and still found only fragmentary developing galaxies.

Recent observations from Hubble's new Wide Field Camera 3, installed last May, pushed into near-infrared wavelengths (first pioneered by Hubble's Near Infrared Camera and Multi Object Spectrometer in 1997). This allowed it to identify objects at a staggering redshift of 9,



Hubble peered deeper into the universe than ever before with its Hubble Ultra Deep Field (HUDF), released in 2004; in 2009, it released a new, even farther-seeing version, shown here. NASA/ESA/G. Illingworth (UCO/Lick Observatory and the University of California, Santa Cruz)/R. Bouwens (UCO/Lick Observatory and Leiden University)/the HUDF09 Team

Like watching individual frames of a motion picture, the Hubble deep surveys reveal the emergence of structure in the infant universe and the subsequent dynamic stages of galaxy evolution.



Galaxies collide in this detail from the HUDF, proving that the universe is a dynamic, changing place. The HUDF uncovered several other instances of colliding galaxies, recasting them from a rare curiosity to a common occurrence. NASA/ESA/ S. Beckwith (STScI)/the HUDF Team

corresponding to when the universe was only 600 million years old.

Like watching individual frames of a motion picture, the Hubble deep surveys reveal the emergence of structure in the infant universe and the subsequent dynamic stages of galaxy evolution. Before Hubble, nearby colliding galaxies were simply a curiosity. But these deep views showed that the galactic smashups were more the rule than the exception in the early days. This provided compelling, direct visual evidence that the universe truly changes as it ages.

2 Supermassive black holes are common in galaxies

When Hubble launched, scientists had only confirmed the existence of black holes in stellar binary systems, where a companion star explodes and its core collapses to a black hole of several solar masses. But astronomers suspected that far more massive black holes must be the powerful "gravitational engines" powering a wide range of extraordinarily energetic phenomena seen near and far: Seyfert galaxies, BL Lac objects, blazars, and, above all, the mysterious quasars (short for quasi-stellar radio sources, now widely thought to be the supermassive black holes at the center of distant galaxies).

But precision spectroscopy was necessary to "weigh" a black hole to see if the amount of hidden or "nonluminous" mass far exceeded what mass could be attributed to stars alone. When the Space Telescope Imaging Spectrograph (STIS) became operational in 1997, astronomers quickly aimed it at the nearest mini-quasar, the brilliant core of giant elliptical galaxy M87 in Virgo. Like far more distant quasars, the galaxy has a telltale jet of material ejected from the core at relativistic speeds, a behavior commonly associated with black holes.

Hubble measured a 3-billion-solar-mass core in M87. This was possible because the STIS made velocity measurements of a never-before-seen spiral-shaped whirlpool of hot gas orbiting around the black hole. The disk's velocity indicates a concentration of mass vastly higher than what stars alone could contribute, confirming the presence of a black hole.

A 1997 census of 27 nearby galaxies found that they all had supermassive black holes at their centers. This led astronomers to conclude that supermassive black holes are so common that every major galaxy has one.

Even more profound, Hubble discovered that the mass of a central black hole is directly related to the mass of a galaxy's central bulge of stars: The bigger the bulge, the more massive the black hole. This links a galaxy's evolution to the growth of its black hole through some unknown feedback mechanism. Presently, six viable theories exist. This means that no one is absolutely sure what the galaxy-black hole connection is.

3 Dark energy exists

A key project for Hubble astronomers was to determine how fast the universe is decelerating. The reasoning was that gravity must be exerting drag on the

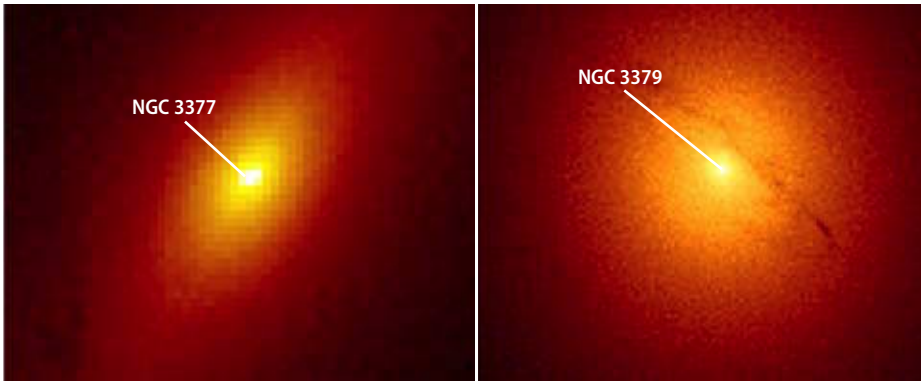
expansion of space after the Big Bang, like a ball rolling up a gentle incline and eventually slowing down.

The question persisted for decades as to whether enough gravity exists to halt the universe's expansion altogether. Hubble's ability to see distant type Ia supernovae and precisely measure their brightness allowed astronomers to look further back into time to measure the expansion rate.

In 1998, Johns Hopkins University/STScI astronomer Adam Riess wrote a computer program to calculate the universe's deceleration rate using the supernova survey data his team collected. Strangely, the program kept coming up with a negative mass for the universe. Riess at first thought this was simply a programming error. But then he realized that the computer program was trying to make sense out of the nonsensical: Empty space produces repulsive energy!

In California, another team led by Saul Perlmutter of Lawrence Berkeley National Laboratory independently discovered a similar acceleration to the universe. His team likewise found that distant supernovae were dimmer than predicted. This meant there was more space between them and us than if the universe were slowing down, or even "just coasting." Therefore, the universe must now be expanding at a faster rate than earlier in time.

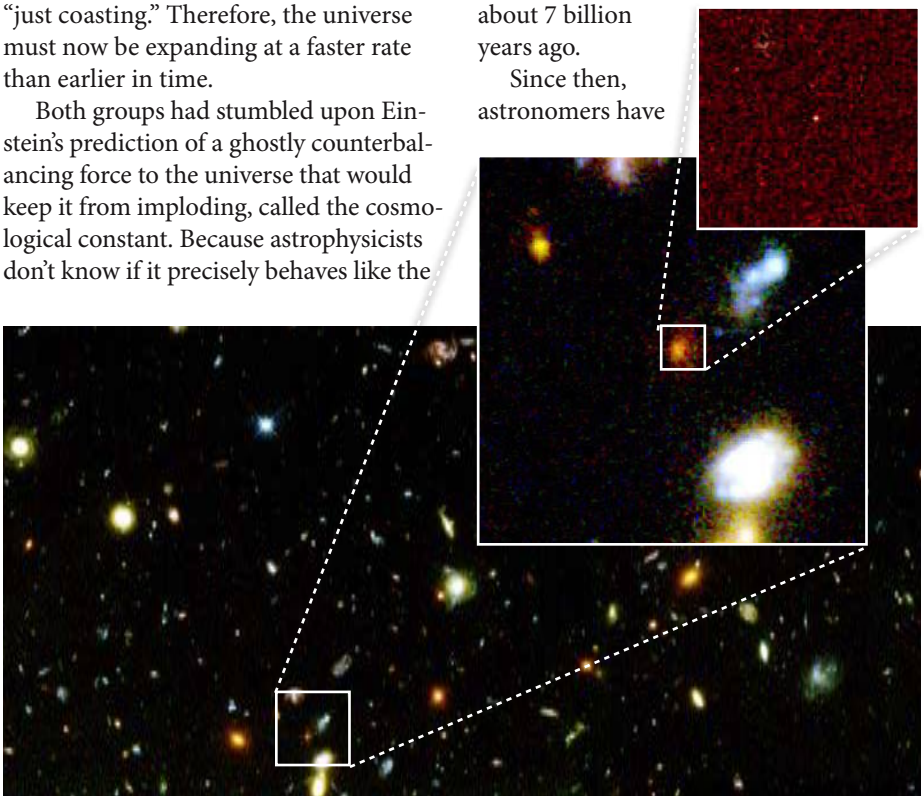
Both groups had stumbled upon Einstein's prediction of a ghostly counterbalancing force to the universe that would keep it from imploding, called the cosmological constant. Because astrophysicists don't know if it precisely behaves like the cosmological constant, the phenomenon is now simply known as dark energy.



Supermassive black holes are now known to be common in the centers of most galaxies, thanks to Hubble. At right, the elliptical galaxy M87 shoots out a giant jet of material, a common symptom of black holes. Above, galaxies NGC 3377 and NGC 3379 have also been proven to house supermassive black holes in their centers. NASA/John Biretta (STScI/JHU); Karl Gebhardt (University of Michigan)/Tod Lauer (NOAO)/NASA

Hubble later bolstered the reality of dark energy when it observed a supernova 10 billion years into the past. It was anomalously bright, demonstrating that the universe was decelerating very long ago, but between then and now it sped up. This transition from "push me, pull you" happened about 7 billion years ago.

Since then, astronomers have pursued observations to better characterize dark energy and to see if it really does behave like Einstein's cosmological constant. Scientists have proposed several approaches for next-generation telescopes, including surveys to find more supernovae and measuring acoustic oscillations imprinted on the sky, triggered by forces in the primordial plasma of the Big Bang.



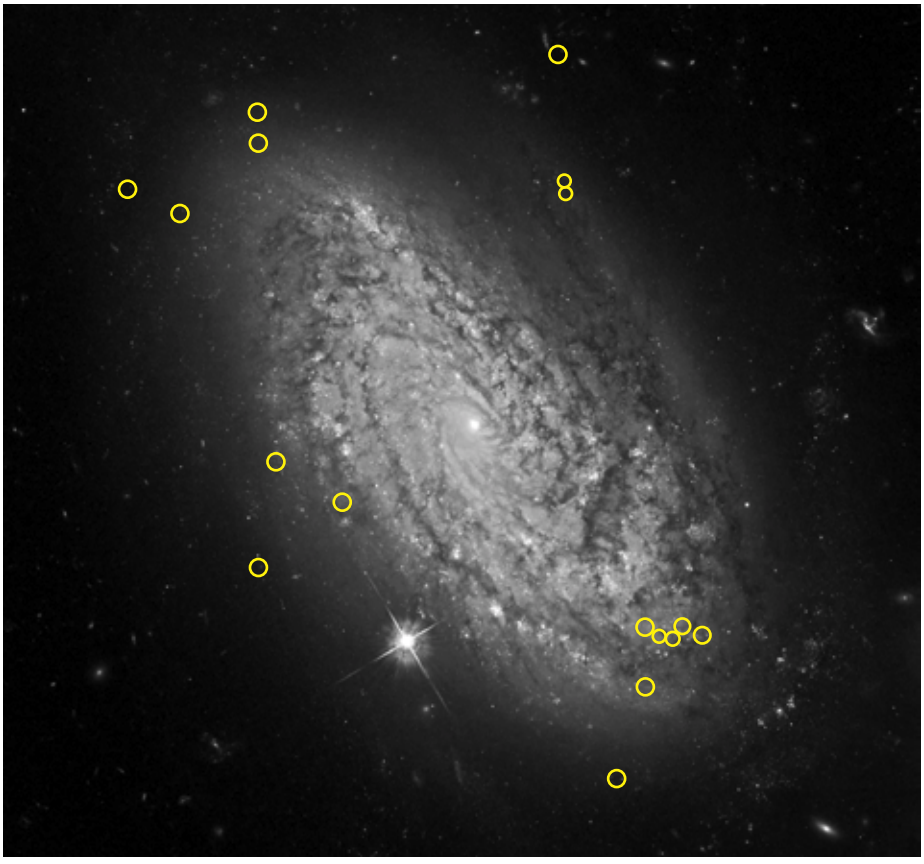
The glow of a 10-billion-year-old supernova, shown above, helped prove the existence of a mysterious, repulsive force astronomers have named dark energy. NASA/A. Riess (STScI)

4 The universe's expansion rate nailed down

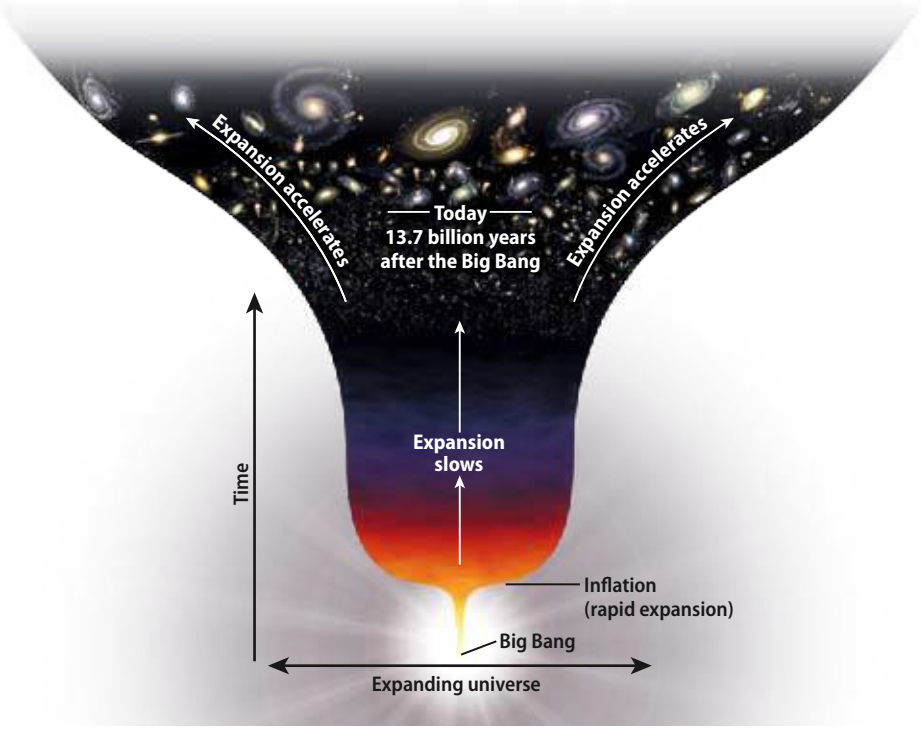
Scientists of the late 1800s imagined a very old Earth because of geologic evidence and Charles Darwin's concept of biological evolution. Even the great mind of Albert Einstein concluded that the universe must be static and perhaps therefore eternal. Otherwise it would have flown apart or collapsed according to his general theory of relativity.

In 1929, Edwin Hubble provided the first observational evidence that indicated the universe has a finite age. The Hubble constant, as it became known, showed that the farther a galaxy is, the faster it appears to be racing away from us. This means space expands in all directions. In fact, the reddening of light is not the result of velocity — as it would be if this were truly a Doppler effect — but rather the expansion of space stretching light into longer wavelengths.

By precisely determining the expansion rate, scientists can rewind the cosmic clock and calculate the age of the uni-



Spiral galaxy NGC 3021, shown in this Hubble photograph, was one of many galaxies that helped astronomers nail down the universe's expansion rate because it is home to both Cepheid variable stars (in yellow) and type Ia supernovae. The Cepheids, whose distances can be easily determined, served to "calibrate" the supernovae, allowing scientists to use the stellar explosions as galactic mile markers throughout the universe. NASA/ESA/A. Riess (STScI/JHU)



The universe's expansion hasn't been completely even at all times, as this diagram shows. At first it grew tremendously quickly in a process called inflation, then it grew more slowly until around 7.5 billion years ago, when it began to grow more and more quickly. Scientists think dark energy is responsible for this increasing pace of expansion. *Astronomy*: Roen Kelly

verse. But the age estimate is only as reliable as the accuracy of the distance measurements. A precise value for the Hubble constant is a critical anchor point for calibrating other cosmological parameters for the universe (and, in hindsight, for characterizing dark energy — which no one even suspected in 1990).

This became a Key Project for Hubble early on because a space telescope could resolve Cepheid variable stars, a type of star that can serve as a local cosmic milepost, out to much greater distances from Earth than ground-based telescopes could.

When Hubble launched, the expansion rate of the universe had a huge degree of uncertainty. Estimates ranged from 50 kilometers per second per megaparsec to 100 km/sec/Mpc. This meant that the universe could be as young as 8 billion years or as old as 16 billion years.

In 1994, Wendy Freedman of the Hubble Space Telescope Key Project on the Extragalactic Distance Scale announced a value of 80 km/sec/Mpc, implying a relatively young universe. The results were perplexing because they suggested a universe 8 billion to 12 billion years old, which is younger than the oldest stars. It looked like stellar evolution models were inaccurate.

By the late 1990s, the refined the value of the Hubble constant had an error of only about 10 percent. In 2009, Adam Riess and collaborators streamlined and strengthened the construction of a cosmic "distance ladder" by calibrating Cepheids in faraway galaxies. This allowed astronomers to measure precisely the expansion rate to be 74.3 km/sec/Mpc, narrowing it to a value with an uncertainty of no more than 5 percent.

In hindsight, it was almost predictable that astronomers would simply end up splitting the difference between the earlier values of 50 km/sec/Mpc and 100 km/sec/Mpc. With dark energy factored in, this yields an age of 13.7 billion years — old enough to accommodate the measured ages of the oldest stars.

5 Sampling the atmospheres of extrasolar planets

Astronomers did not discover an extrasolar planet around a normal star until 5 years after Hubble's launch. The exoplanets were too dim for ground-based telescopes of the time to directly see them,

Exoplanets, or planets that orbit stars outside our solar system, had long been a mere theoretical possibility. Thanks to Hubble, scientists can visibly detect exoplanets and even observe their atmospheres. At top is HD 209458, a star of 7th-magnitude about 150 light-years away in Pegasus the Winged Horse, which is home to exoplanet HD 209458b. Despite being almost unimaginably distant, its light tells scientists much about this world. ESA/NASA/Digitized Sky Survey

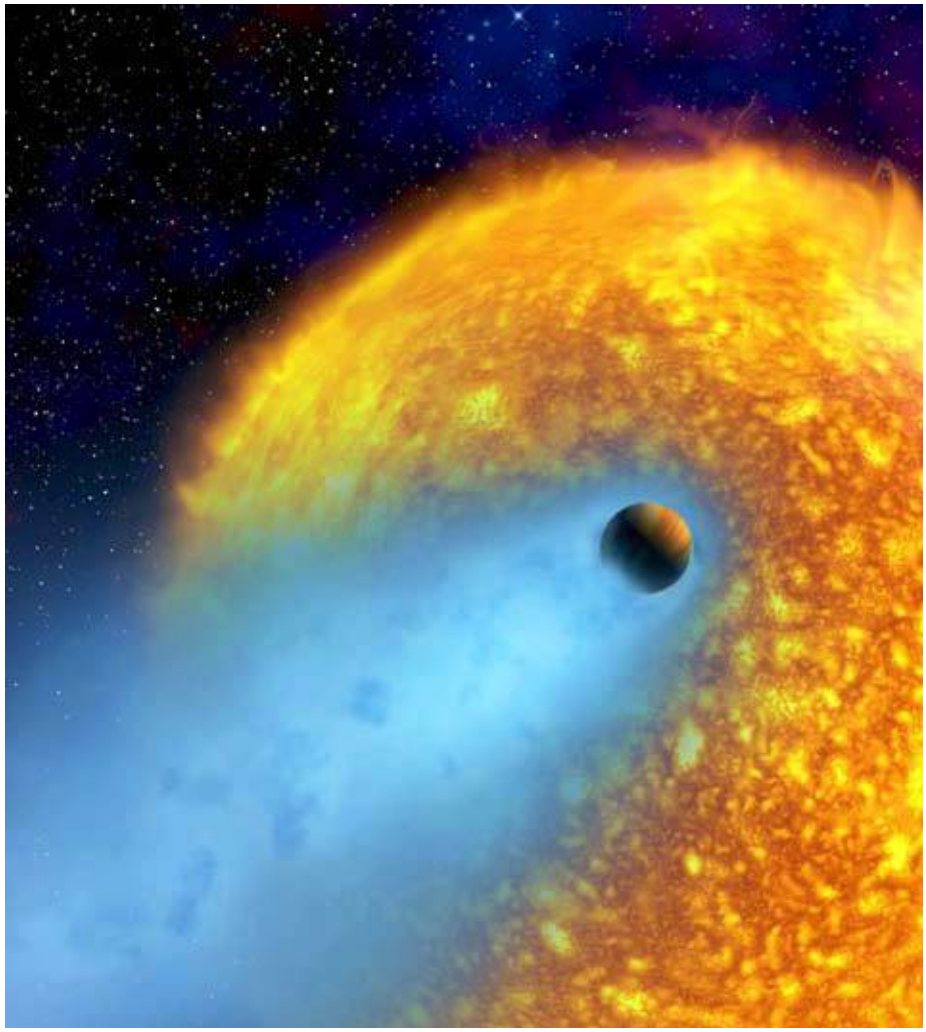
but the rhythmic wobble of the parent star yielded telltale evidence for the tug of a planetary companion. The only information this provided was the orbital period and a rough mass estimate for exoplanets.

But by the late 1990s, astronomers had detected extrasolar planets transiting (passing in front of) their stars. This opened up the possibility for characterizing these worlds because a planet could be measured in silhouette against its parent star. Astronomers quickly applied Hubble's unique capabilities to the exoplanet sweepstakes.

Hubble made the first measurements of the atmosphere of an exoplanet. In a landmark observation, David Charbonneau of Harvard University spectroscopically measured a parent star's light as it filtered through an exoplanet's atmosphere. He found sodium present in the atmosphere of HD 209458b.

In subsequent observations, Hubble has found carbon dioxide, oxygen, and water vapor on transiting exoplanets. The hot Jupiter class planets are no doubt lifeless, but Hubble's capability to analyze their atmospheres is an important proof of concept in the search for extraterrestrial life by looking for atmospheric biotracers on earthlike planets.

Despite these strides, direct imaging of exoplanets proved elusive even for Hubble. That had to wait until 2008 when Hubble made the first-ever visible-light image of a young gas giant orbiting the star Fomalhaut.



This artist's depiction of exoplanet HD 209458b highlights one of its more exotic qualities: the evaporation of much of its atmosphere. ESA/Alfred Vidal-Madjar (Institut d'Astrophysique de Paris, CNRS, France)/NASA

Today, Hubble is 100 times more powerful and efficient than when it launched in 1990. It should continue operating well into the new decade.

What's next?

Thanks to the space shuttle program and its teams of astronauts, Hubble's cameras have seen upgrades with state-of-the-art instrumentation. Today, Hubble is 100 times more powerful and efficient than when it launched in 1990. It should continue operating well into the new decade.

Several key legacy programs are in place to extract the maximum science from the telescope's golden years. One program will study the distribution of dark matter in the universe by measuring gravitational lensing in 25 giant galaxy clusters. Hubble will also take multiple deep fields to catalog 250,000 remote galaxies. Another ambitious program will do a huge color photo mosaic of stars and nebula in a quadrant of the neighboring Andromeda Galaxy (M31).

Thus, Hubble's best discoveries may well still lie ahead.

Find out how to find Hubble in the nighttime sky at www.Astronomy.com/toc.

The Sky this Month

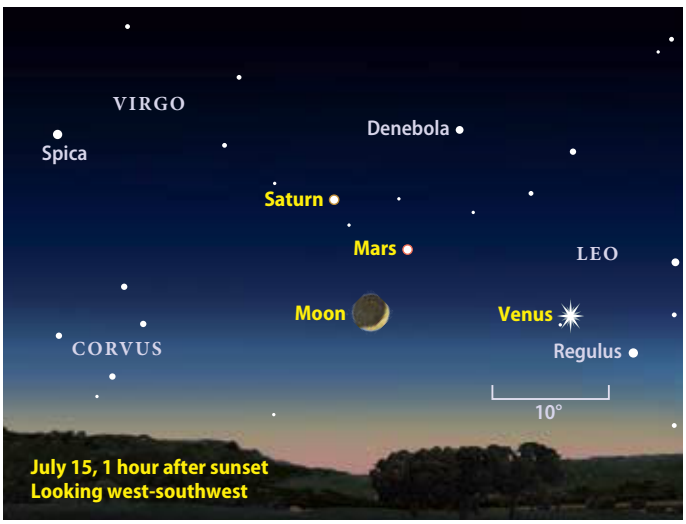
Martin Ratcliffe and Alister Ling describe the solar system's changing landscape as it appears in Earth's sky.

July 2010

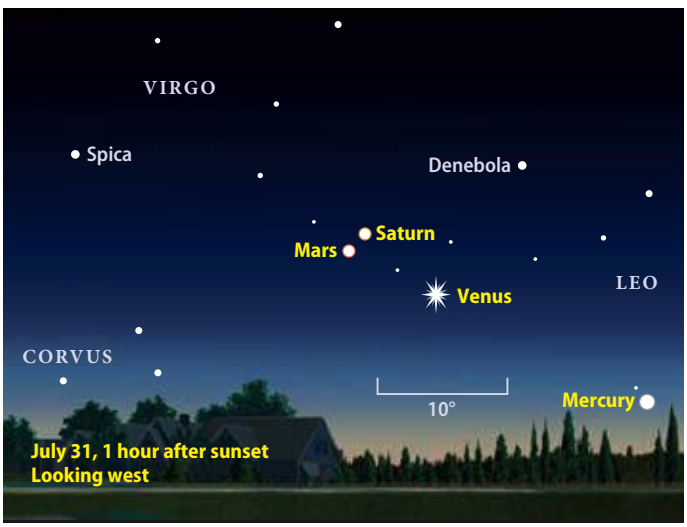
The Sun's disappearing act

Three planets line up in the western sky these warm summer evenings. Venus — easily the brightest of the trio — punctuates the twilight shortly after the Sun goes down.

Saturn follows Venus into view, and fainter Mars shows its ruddy face not long after. Mercury joins the parade in mid-July at about the same time a crescent Moon passes through the area.



Three planets line up in the evening sky in mid-July. Coincidentally, the Moon passes by at the same time. *Astronomy:* Roen Kelly



Mars and Saturn pass each other at July's close. Note the color contrast between ruddy Mars and golden Saturn. *Astronomy:* Roen Kelly

All four of these planets set by midnight, leaving the morning sky to brilliant Jupiter and its dimmer cousins, Uranus and Neptune. Despite the fine planetary smorgasbord available every clear July night, the month's highlight takes place during daylight hours July 11 when the Moon passes directly between the Sun and Earth. Lucky observers along a narrow path in Earth's Southern Hemisphere will see a total solar eclipse.

But our tour of the sky begins where it usually does, in the western sky shortly after nightfall. Casual observers might think that the three bright objects in a row are aircraft stacked up for a landing. But these luminaries are planets much farther away. Venus shines brightest and lies closest to the horizon. During most of July, Saturn stands to Venus' upper left with Mars in between. Around the 30th, however, Saturn and Mars switch places.

The gap separating these planets shrinks throughout the month. On July 1, Venus and Saturn lie 40° apart. By the 31st, all three planets crowd into a field just 8° across.

Venus dominates the scene. It shines at magnitude –4.1 in early July and grows brighter, reaching magnitude –4.3 by month's end. No other point of light comes close — the brightest evening stars appear some 40 times fainter.

36 An evening lineup of planets
41 Meteor watch
41 Rising Moon
42 When to view the planets
42 Moons on the move
42 Comet search
43 Locating asteroids
43 The Sun in eclipse

Visible to the naked eye
Visible with binoculars
Visible with a telescope

Venus spends July among the background stars of Leo. The planet begins the month in far western Leo, near the constellation's border with Cancer, and ends the month at the Lion's opposite end. On July 9, Venus passes 1° north of Leo's brightest star, 1st-magnitude Regulus.

As you might guess from the planet's brightening, Venus is getting closer to Earth. Its distance diminishes from 100 million miles to 78 million miles during July. This translates into a growing disk when you view Venus through a telescope. Its apparent diameter this month waxes from 16" to 20". Over the same period, the planet's gibbous phase wanes from 71 percent to 58 percent lit.

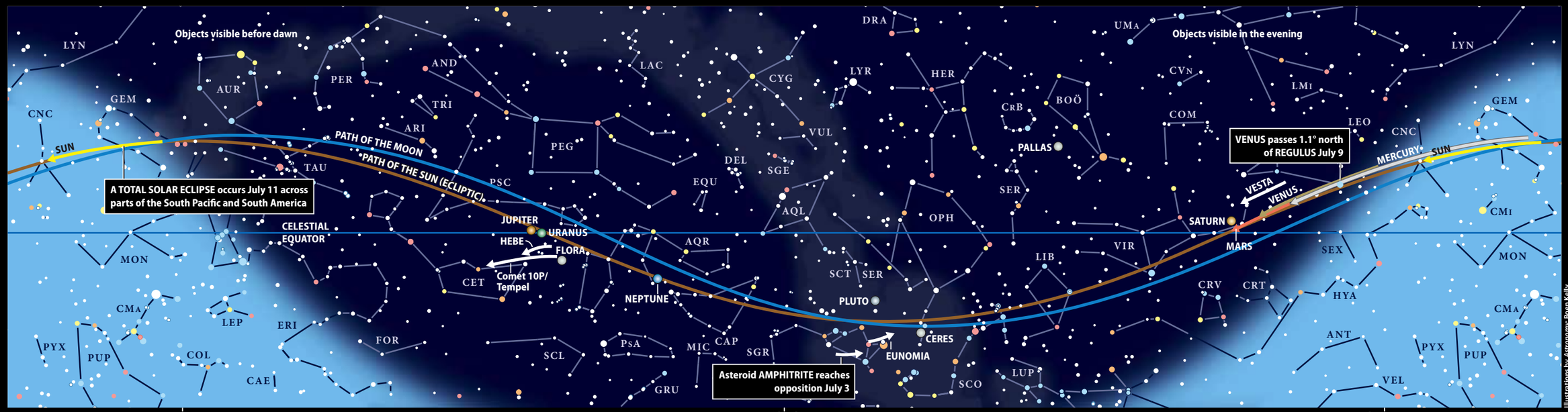
— *Continued on page 41*

Planets in July 2010

This map unfolds the entire night sky from sunset (at right) until sunrise (at left).
Arrows and colored dots show motions and locations of solar system objects during the month.

Astronomy magazine

Path of the planets



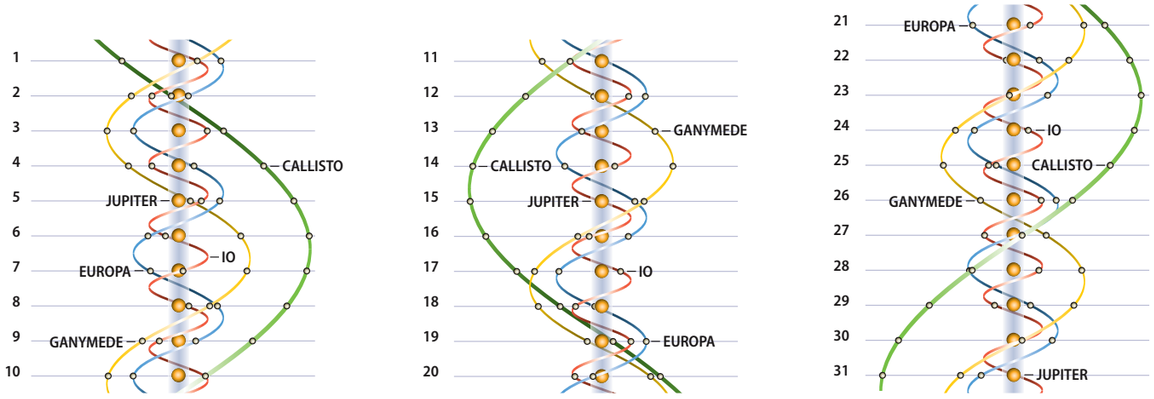
MOON PHASES

To locate the Moon in the sky, draw a line from the phase shown for the day straight up to the curved blue line.
Note: Moons vary in size due to distance from Earth and are shown at 0h Universal Time.

PLANETS	MERCURY	VENUS	MARS	CERES	JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
Date	July 31	July 15	July 15	July 15	July 15	July 15	July 15	July 15	July 15
Magnitude	0.1	–4.2	1.4	7.7	–2.6	1.1	5.8	7.8	14.0
Angular size	6.8"	17.2"	5.0"	0.7"	43.4"	16.8"	3.6"	2.3"	0.1"
Illumination	59%	65%	92%	99%	99%	100%	100%	100%	100%
Distance (AU) from Earth	0.989	0.971	1.889	1.935	4.539	9.884	19.693	29.188	30.905
Distance (AU) from Sun	0.457	0.724	1.613	2.861	4.966	9.534	20.094	30.019	31.865
Right ascension (2000.0)	10h22.6m	10h28.9m	11h27.6m	17h25.8m	0h13.6m	12h01.2m	0h02.7m	22h01.6m	18h14.6m
Declination (2000.0)	9°48'	10°53'	4°15'	–26°33'	0°00'	2°21'	–0°33'	–12°36'	–18°19'

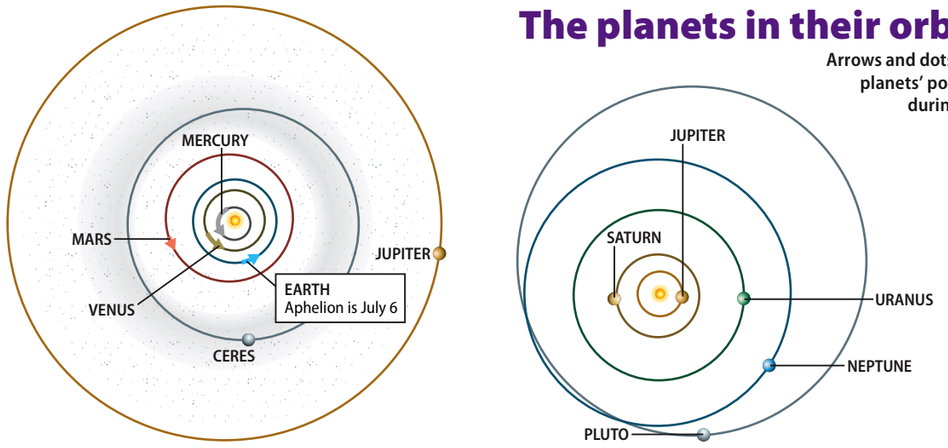
Jupiter's moons

Dots display positions of Galilean satellites at 4 A.M. EDT on the date shown.
South is at the top to match the view through a telescope.



The planets in their orbits

Arrows and dots show planets' positions during July.



StarDome

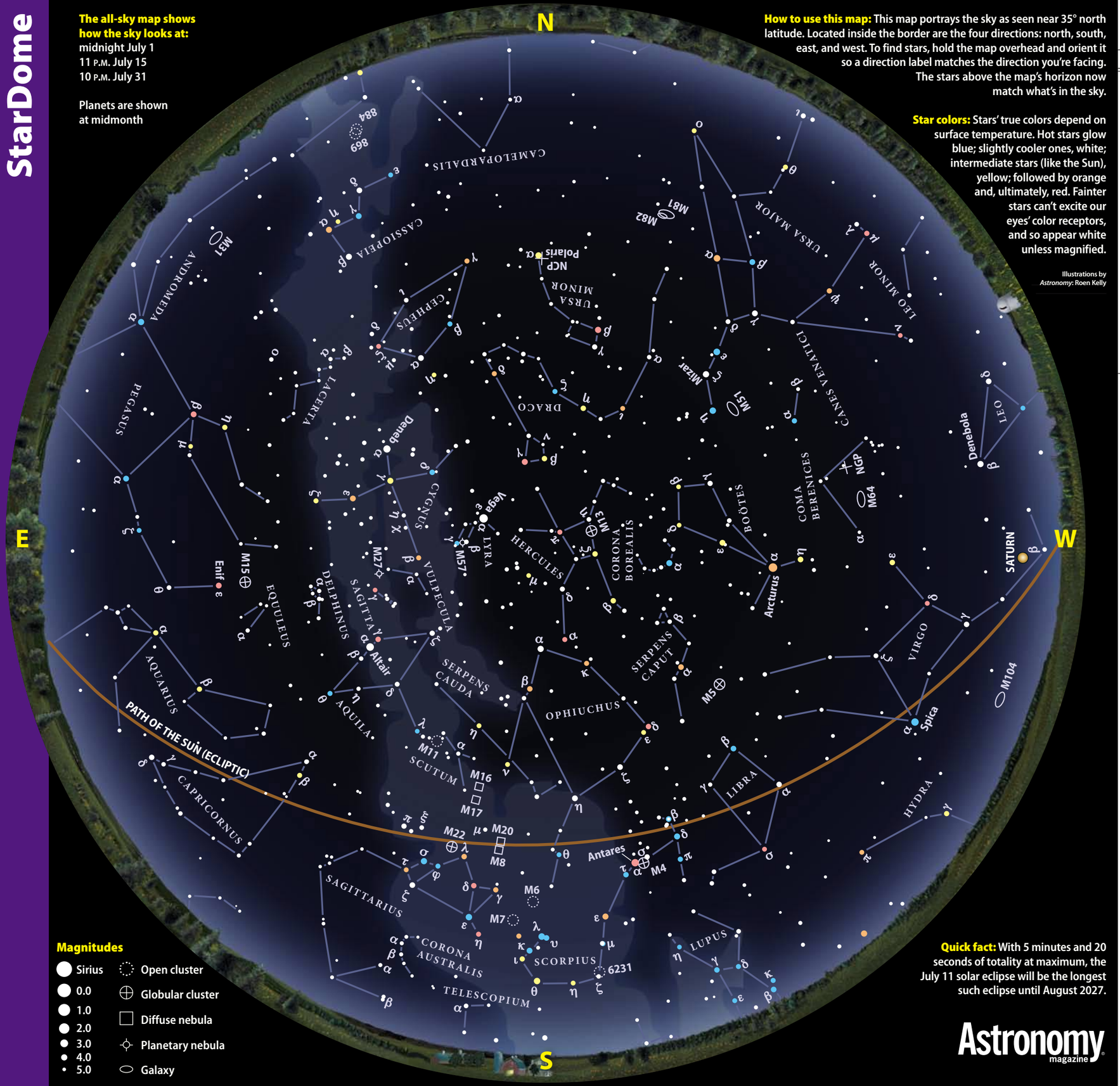
The all-sky map shows how the sky looks at:
midnight July 1
11 P.M. July 15
10 P.M. July 31

Planets are shown at midmonth

How to use this map: This map portrays the sky as seen near 35° north latitude. Located inside the border are the four directions: north, south, east, and west. To find stars, hold the map overhead and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

Star colors: Stars' true colors depend on surface temperature. Hot stars glow blue; slightly cooler ones, white; intermediate stars (like the Sun), yellow; followed by orange and, ultimately, red. Fainter stars can't excite our eyes' color receptors, and so appear white unless magnified.

Illustrations by *Astronomy*: Roen Kelly



Magnitudes

- Sirius
- 0.0
- 1.0
- 2.0
- 3.0
- 4.0
- 5.0
- Open cluster
- Globular cluster
- Diffuse nebula
- Planetary nebula
- Galaxy

Quick fact: With 5 minutes and 20 seconds of totality at maximum, the July 11 solar eclipse will be the longest such eclipse until August 2027.

Astronomy magazine

July 2010

Note: Moon phases in the calendar vary in size due to the distance from Earth and are shown at 0h Universal Time.

SUN.	MON.	TUES.	WED.	THURS.	FRI.	SAT.
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	31

Calendar of events

1 The Moon is at apogee (251,678 miles from Earth), 6:12 A.M. EDT

3 Asteroid Amphitrite is at opposition, 7 A.M. EDT

Asteroid Pallas is stationary, 7 A.M. EDT

The Moon passes 7° north of Uranus, 4 P.M. EDT

The Moon passes 7° north of Jupiter, 9 P.M. EDT

4 Last Quarter Moon occurs at 10:35 A.M. EDT

5 Uranus is stationary, 9 P.M. EDT

6 Earth is at aphelion (94.5 million miles for the Sun), 7 A.M. EDT

8 Asteroid Juno is in conjunction with the Sun, midnight EDT

9 Venus passes 1.1° north of Regulus, 11 P.M. EDT

11 New Moon occurs at 3:40 P.M. EDT

12 The Moon passes 4° south of Mercury, 9 P.M. EDT

13 The Moon is at perigee (224,386 miles from Earth), 7:22 A.M. EDT

14 The Moon passes 6° south of Venus, 9 P.M. EDT

16 The Moon passes 6° south of Mars, 1 A.M. EDT

The Moon passes 8° south of Saturn, 3 P.M. EDT

18 First Quarter Moon occurs at 6:11 A.M. EDT

23 Jupiter is stationary, midnight EDT

25 Full Moon occurs at 9:37 P.M. EDT

27 Mercury passes 0.3° south of Regulus, 7 P.M. EDT

28 The Moon passes 5° north of Neptune, 3 A.M. EDT

Southern Delta Aquarid meteor shower peaks

The Moon is at apogee (252,249 miles from Earth), 7:48 P.M. EDT

30 The Moon passes 6° north of Uranus, 11 P.M. EDT

31 The Moon passes 7° north of Jupiter, 5 A.M. EDT

Special observing date

11 A total solar eclipse graces the sky along a narrow path that cuts across the South Pacific and South America.

See tonight's sky in Astronomy.com's STARDOME

— *Continued from page 36*

Although it appears less than 1 percent as bright as Venus, **Mars** still ranks among the brighter evening objects. It shines at magnitude 1.4, almost imperceptibly dimmer than its western neighbor Regulus. Although these two shine with nearly equal intensity, their colors contrast noticeably. Mars sports a distinct ruddy hue while Regulus appears blue-white. Alas, the time for viewing Mars through a telescope has passed. The Red Planet spans only 5", too small to show detail in any but the largest backyard scopes.

Mars' color also contrasts nicely with the pale yellow of **Saturn**. The ringed planet begins July some 15° to Mars' upper left. But this gap closes rapidly, and the two approach within 2° of each other by month's end. Saturn then shines at magnitude 1.1, as it does all month, and appears slightly brighter than its planetary neighbor.

During July, Saturn moves slowly eastward against the backdrop of western Virgo. This position leaves a brief window for observing Saturn through a telescope before it dips too low. For the best views, start about an hour after sunset. Saturn's disk currently measures 17" across the equator and 15" through the poles. The rings span 38" and tilt 3° to our line of sight.

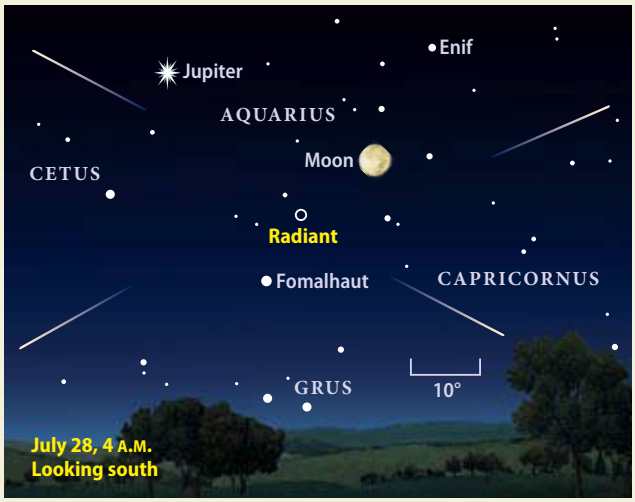
Saturn's moons always put on a good show for backyard observers. Any scope reveals 8th-magnitude Titan, and a good 4-inch scope also captures 10th-magnitude Rhea, Tethys, and Dione. You'll need a telescope double that aperture to reliably spot 12th-magnitude Enceladus.

Keep an eye open for close conjunctions among these moons. One of this month's best occurs July 11 when Rhea and Dione approach within 1" of each other. In small scopes, the two will appear to merge. Look for the same two moons about 3" apart July 17.

On July 27, Titan, Dione, Rhea, and Enceladus all lie within 30" (less than the rings' apparent diameter) of one

Martin Ratcliffe *provides professional planetarium development for Sky-Skan Inc. in Nashua, New Hampshire. Meteorologist* **Alister Ling** *works for Environment Canada in Edmonton, Alberta.*

Meteor watch



The Delta Aquarid meteor shower peaks before dawn July 28. Unfortunately, a nearly Full Moon lies nearby and will drown out all but the brightest meteors. *Astronomy*: Roen Kelly

The Delta Aquarids battle moonlight

When the calendar turns to late July, meteor lovers anticipate the peak of the Delta Aquarid shower and the start of August's Perseid shower. This year, however, the view will be less than spectacular.

The Delta Aquarids peak before dawn July 28, less than 3 days after a Full Moon. Typically, the shower produces 15 to 20 meteors per hour at its peak, but moonlight will drown out fainter meteors and leave only the bright ones. You'll be lucky to see half of the normal peak rate. The darker skies in mid-July may prove just as rewarding. If you observe far from the lights of the city, you should see at least 5 meteors per hour coming from random directions. It may not be enough to warrant a special trip to the country, but if you're out observing the other sights of the night sky, keep your eyes peeled for these stragglers.

The good news: The Perseid meteor shower peaks the night of August 12/13, just after New Moon, and should put on a spectacular display next month.

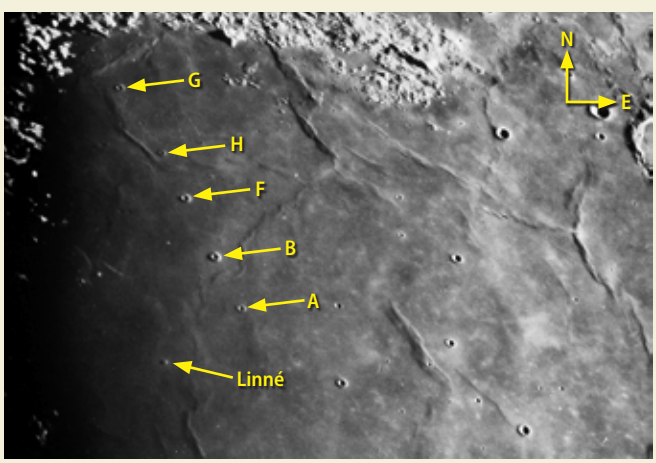
Rising Moon

A heartfelt sunrise comes to Serenity

The Sea of Serenity's dark floor comes alive with pits, bumps, and ridges when sunlight slices the Moon in half. On July 16, the snaking Serpentine Ridge will capture your attention. Its long play of light and dark highlights Mare Serenitatis (the Sea of Serenity), the huge impact basin north of the lunar equator.

By July 17, the Sun has risen over the eastern half of Serenity's ancient lava-filled bowl. This brings to light some comparatively young impact craters. Strung out in a line from north to south are Linné G, H, F, B, and A, with Linné itself to their southwest. Linné F and B are the biggest, although even they barely span 3 miles.

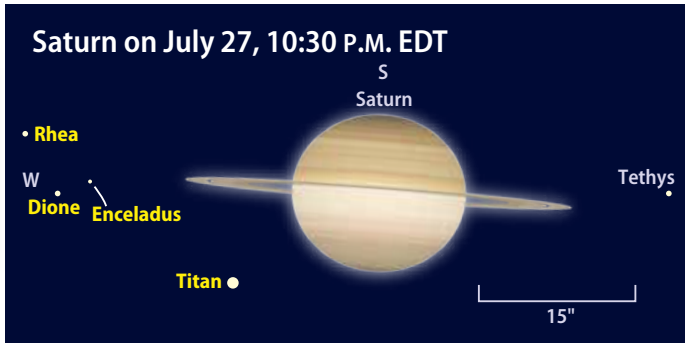
The "Valentine Dome" is a gentle volcanic protrusion tucked against the western flank of Serenity. It appears only at the lowest Sun angles, like those on the 17th. Its somewhat heart-shaped swelling crests less than 400 feet above the basin floor. You can't miss the handful of older peaks that stick above the dome. One Earth night later (July 18), the shade of the gentle slopes disappears under the higher Sun, leaving but a trace of the tiny tops.



A string of craters named after the bright impact feature Linné pock the vast expanse of the Sea of Serenity. This area stands out well around First Quarter Moon. *Consolidated Lunar Atlas*/UA/LPL

When to view **the planets**

EVENING SKY	MIDNIGHT	MORNING SKY
Mercury (west)	Jupiter (east)	Jupiter (south)
Venus (west)	Uranus (east)	Uranus (south)
Mars (west)		
Saturn (west)		



Four of Saturn's moons lie near one another July 27. Three appear west of the rings and the fourth, Titan, lies northeast of the trio. *Astronomy:* Roen Kelly

another. And one night later, Enceladus and Tethys sit 10" apart near the western edge of the rings while Titan lies 10" due north of Dione on the opposite side.

Mercury joins the other evening planets in mid-July. On the 15th, it lies 6° high in the west-northwest 30 minutes after sunset. It then shines at magnitude –0.5, bright enough to show up against the twilight.

Although Mercury's evening altitude changes little during July's second half, it becomes harder to see because it dims. By the 31st, it shines at magnitude 0.1, barely half as bright as it was in mid-July. Mercury passes 0.3° south of Regulus July 27, but viewing this conjunction will be difficult without binoculars.

The view of Mercury through a telescope isn't much better. The innermost planet appears 5.6" across and 81 percent lit July 15. By the 31st, it spans 6.8" and shows a disk slightly more than half-lit.

A waxing crescent Moon slides below the evening planets around midmonth. On July 12, a 1-day-old Moon appears 4° to Mercury's lower left. (You'll need clear skies and an unobstructed horizon to see the pair.) Two evenings later, look for a thicker crescent Moon about 6° to Venus' lower left. And on the 15th, a quarter-lit Moon lies 6° to Mars' lower left and about 10° below Saturn.

By late evening, diminutive **Pluto** appears at its best — although that's not saying a lot. The distant dwarf planet glows dimly at 14th magnitude against the rich star fields of Sagittarius, a double whammy that makes a visual sighting through a telescope difficult. You'll need a 10-inch or larger scope and a dark sky to spot it. Imaging it with a CCD camera is significantly easier — the same scope can record Pluto with an exposure of just a few seconds.

Pluto reached opposition in late June, so it now lies highest in the sky during the late evening. You can find the planet 4° west of the open star cluster M25 and 5° north of the Trifid Nebula (M20).

Pluto's closest neighbor among the planets, in the solar system as well as the July sky, is **Neptune**. In mid-July, the giant planet rises in late evening and appears about 20° high in the southeast by midnight local daylight time. Neptune glows at magnitude 7.8 and shows up easily through binoculars.

Neptune lies in Aquarius, near this constellation's border with Capricornus. If you center 4th-magnitude Iota (ι) Aquarii in your binoculars, Neptune will be the dim object nearly 2° northwest of this star. Alternatively, look roughly midway along the imaginary line that joins the 5th-magnitude stars Mu (μ) Capricorni and 38 Aquarii. A telescope shows Neptune's blue-gray disk, which measures 2.3" across.

After midnight, look for Jupiter and Uranus climbing together in the eastern sky. You won't have any trouble finding **Jupiter**, which gleams at magnitude –2.6. It's the

Comet search

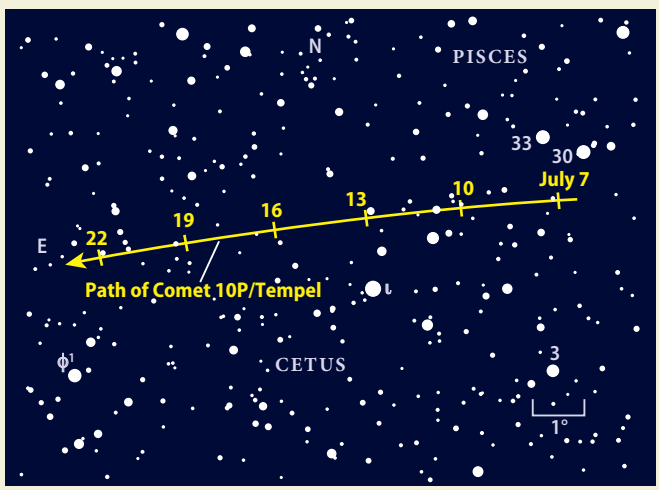
Tempel eyes a tremendous transformation

July offers a chance to tag along for a fascinating ride as a comet and Earth arc around the inner solar system. Our shifting perspective helps paint a partial three-dimensional picture of Comet 10P/Tempel's head and tail. And with some luck, we may witness a mini-outburst.

A comet's tail has a shape reminiscent of an old-fashioned hand fan: It spreads out in a flat veil from the nucleus. When seen edge-on, the tail appears bright and straight. This happens to 10P/Tempel the night of July 19/20 (wait for it to climb higher after midnight), but it still should be prominent a night or two before and after.

Comet 10P/Tempel usually performs consistently. For this apparition, astronomers expect it to peak near 8th magnitude. Historically, however, Tempel occasionally jumps a couple of magnitudes a week or two after its closest approach to the Sun. During this apparition, that coincides nicely with its edge-on appearance in mid-July.

Comet 10P/Tempel earned its designation because it was the 10th comet astronomers recognized as periodic. German-born astronomer Ernst Wilhelm Tempel first spotted this object in 1873. He also recovered the comet on its first predicted return in 1878.



Comet 10P/Tempel should peak this month at around 8th magnitude among the stars of Cetus. With some luck, however, it may have an outburst and appear two magnitudes brighter. *Astronomy:* Roen Kelly

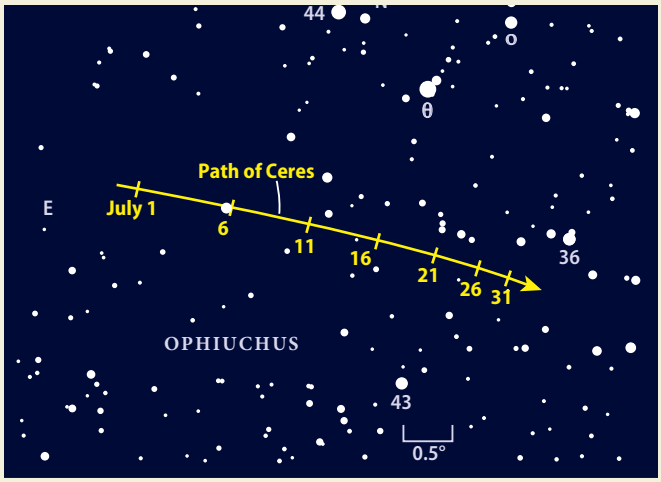
Locating **asteroids**

Ceres pierces the dark Pipe

Ceres lies near the Milky Way's heart this month. Normally, the asteroid's 7th-magnitude glow would be nearly lost in this stellar crowd. But a dark cloud of dust and gas known as Barnard 78, which blots out most background stars, should allow you to spot Ceres.

During July, this asteroid passes south of 3rd-magnitude Theta (θ) Ophiuchi, the southernmost bright star in the constellation Ophiuchus. July 6 is the only time you might confuse Ceres with a background star. That night, the asteroid lies next to a 6th-magnitude star (which itself lies 2.5° southeast of Theta). Crank up the magnification on this field star to see if you can split it into two components. Ceres glows 1.5 magnitudes fainter than this pair's combined light. If you return to the scene every hour or so, you'll see the nearby space rock shift relative to the background star.

The dark cloud B78 is one of the most photographed areas of the sky. It marks the hindquarters of the Prancing Horse, in an area well-known as the Pipe Nebula. By the end of July, Ceres has moved from the Pipe's bowl to its stem.



Asteroid Ceres cuts across southern Ophiuchus in July, passing in front of a relatively starless void known as the Pipe Nebula. *Astronomy:* Roen Kelly

brightest point of light in the morning sky, and is even more conspicuous because it lies against the dim backdrop of southern Pisces.

Jupiter looks spectacular through a telescope. The view improves noticeably as the night goes on and the planet climbs higher, where its light passes through less of Earth's image-distorting atmosphere. Jupiter's colorful cloud tops feature two prominent dark belts sandwiching a brighter zone, which runs along the planet's equator. Under good conditions, you'll see a series of alternating belts and zones as well as more subtle features within the belts.

Jupiter grows larger and should look even better as the month progresses. The giant planet spans 41.5" at the beginning of July and 45.6" by month's end.

Adding to the jovian spectacle are four bright moons, which show up through any telescope. Io, Europa, Ganymede, and Callisto waltz back and forth around Jupiter. At times, all four moons lie on one side of the planet. You can see such configurations July 5, 8, and 18.

Each moon crosses in front of and passes behind Jupiter once each orbit. Because Io is the quickest moon, orbiting Jupiter every 1.8 days, it experiences more of these transits and occultations. North Americans can see a nice example July 7. Although the transit begins at 3:34 A.M. EDT, start watching by 2:13 A.M. EDT. That's when Io's black shadow begins to cross Jupiter's face. The shadow shows up better against the jovian cloud tops than Io itself.

When Io moves to the planet's far side, you can see Jupiter and its shadow block the moon from view. Watch Io glide into Jupiter's shadow at 5:04 A.M. EDT July 6 (during twilight in the Eastern time zone). Europa, Ganymede, and Callisto provide similar events throughout the month, although at longer intervals because they take more time to orbit Jupiter.

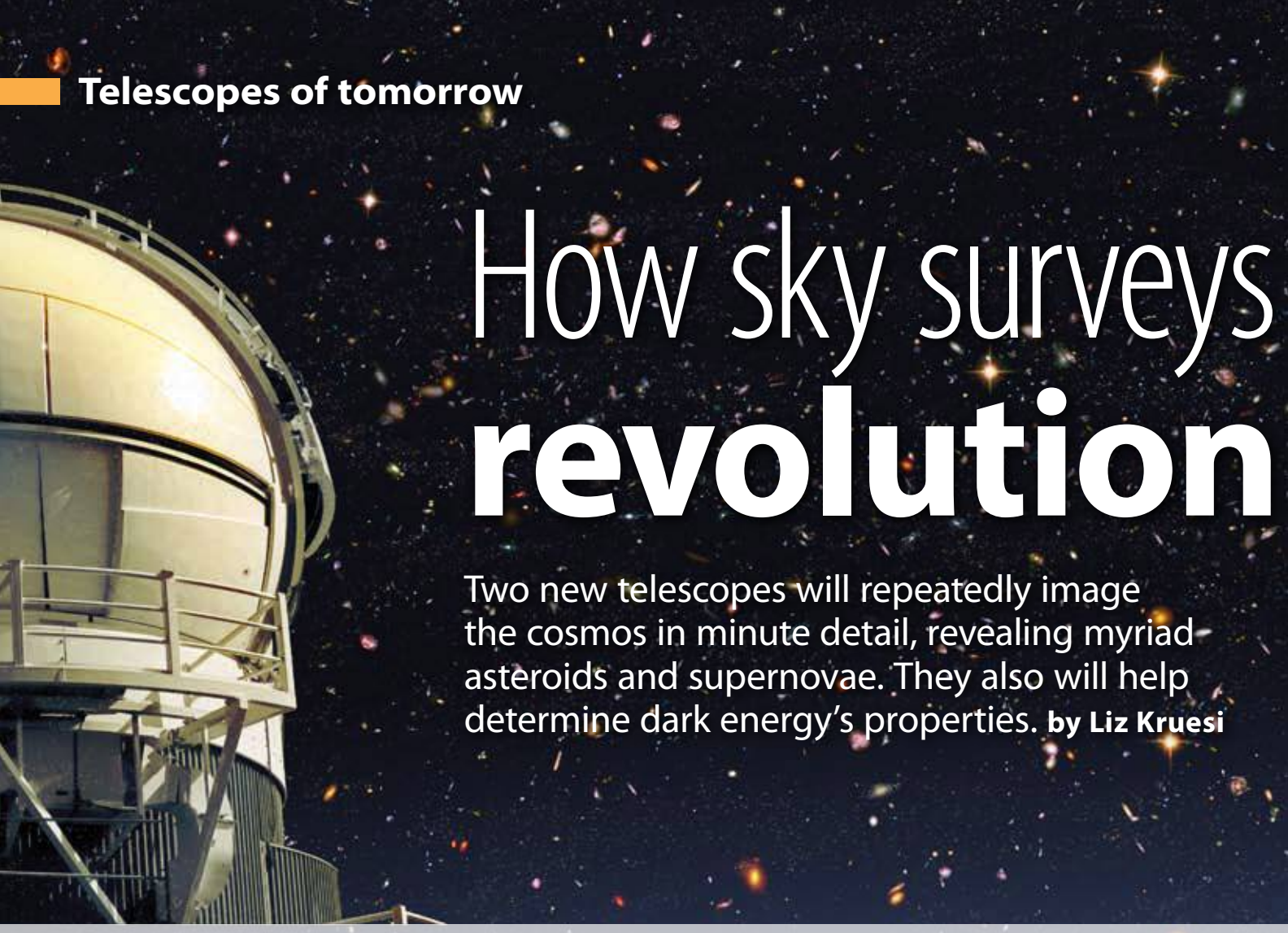
Uranus glows at magnitude 5.8, bright enough to see without optical aid from a dark site but a much easier target through binoculars. A telescope at high magnification reveals a 3.6"-diameter disk with a blue-green color.

The Sun disappears during daylight July 11, when the Moon passes in front and blocks the bright disk from view for observers in the right spot. At maximum, the Sun will be gone for more than 5 minutes. Babak Tafreshi

For much of June, Uranus appeared less than 1° from brilliant Jupiter. But Jupiter moves slowly east of the more distant planet during most of July, and by month's close, 3° separate them.

To find Uranus, place Jupiter on the left side of your binocular field. To its right (west) will be a pair of 6th-magnitude objects. The nearer is a star. The farther one, about one Moon-width beyond, is Uranus.

For a few lucky people, July's top event will be a **total solar eclipse**. On July 11, the Moon passes in front of the Sun and blocks it from view along a thin strip of Earth's surface. The path runs through French Polynesia (passing just south of Tahiti), across Easter Island, and ends in southern South America. At maximum eclipse in the South Pacific, the Moon completely hides the Sun for 5 minutes and 20 seconds.



How sky surveys revolution

Two new telescopes will repeatedly image the cosmos in minute detail, revealing myriad asteroids and supernovae. They also will help determine dark energy's properties. **by Liz Kruesi**

For decades, astronomers have used wide-field sky surveys, but future surveys will record a larger area in less time and gaze far deeper into space. And while this is precisely the direction we'd expect new detector technology to take, two projects in particular, the Panoramic Survey Telescope & Rapid Response System (Pan-STARRS) and the Large Synoptic Survey Telescope (LSST), will revolutionize how astronomers observe the sky.

These upcoming telescopes will have wide fields of view to capture huge portions of the night sky within just a few days. Advanced cameras will document all stars, galaxies, and other static objects the telescopes see. Onboard computer systems will detect changes in a patch of sky from one observation to another. That means they will have the ability to spot millions of objects that change position or brightness, like asteroids, comets, Kuiper Belt objects, and supernovae.

When it's complete, Pan-STARRS will consist of an array of four 1.8-meter telescopes working together as a 3.6-meter instrument atop Mauna Kea, Hawaii. An 8.4-meter mirror will outfit LSST, located at Cerro Pachón, Chile. Both projects will make use of advances in optics, electronics, and supercomputers. And with project scientists putting the data on the Internet, catalogs of science will be widely available. This is astronomy's future.

The big picture

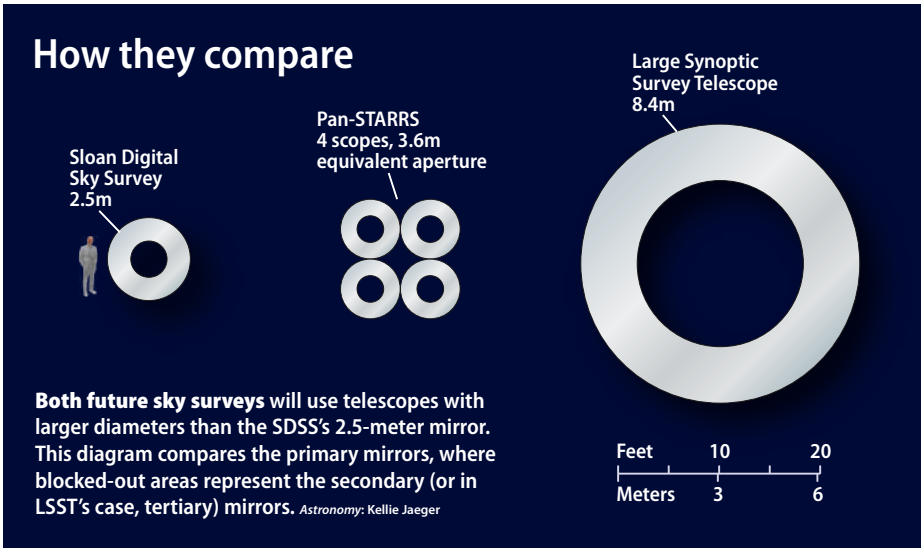
Most telescopes look deeply into a small patch of sky. For example, the Hubble Space Telescope's Wide Field Camera 3 has a field of view of roughly 7 square arcminutes. Compare that to the Sloan Digital Sky Survey's (SDSS) 3-square-degree field of view — that's about 1,500 times bigger. But SDSS sacrifices deep observing for wide views. The next-generation surveys will retain both. Pan-STARRS will have a 7-square-degree field of view and will see down to 24th magnitude in one short 30-second exposure. LSST will push it even further and image magnitude 24.5 objects in 15 seconds within each 9.6-square-degree field — that's about 4,800 times larger than Hubble's.

While similar to the purpose of the SDSS, which since 2000 has been diligently mapping the sky, both Pan-STARRS and LSST will speed things up. Over 10 years, SDSS has concentrated on about 12,000 square degrees of sky and taken some 16 terabytes of images. Pan-STARRS, anticipated to come online in 2013, will observe 6,000 square degrees in an 8-hour night. It will take about a

Associate Editor **Liz Kruesi** *enjoys the science of astronomy. She collaborated with illustrator Roen Kelly to produce "What makes stars tick?" for the June issue.*

will
ize astronomy

The future of wide-field sky surveys rides on the shoulders of the Panoramic Survey Telescope & Rapid Response System (upper left) and the Large Synoptic Survey Telescope (lower right). Both will make significant contributions to many branches of astronomy, including our solar system, the Milky Way Galaxy, and cosmology. *Astronomy*: Kellie Jaeger; Pan-STARRS photo: Brett Simison; LSST illustration: Todd Mason, Mason Productions Inc./LSST Corporation; background galaxies: *Astronomy*: Roen Kelly and NASA/ESA/S. Beckwith (STScI)/The HUDF Team


How they compare
Sloan Digital Sky Survey 2.5m
Pan-STARRS 4 scopes, 3.6m equivalent aperture
Large Synoptic Survey Telescope 8.4m
Feet 10 20
Meters 3 6

Both future sky surveys will use telescopes with larger diameters than the SDSS's 2.5-meter mirror. This diagram compares the primary mirrors, where blocked-out areas represent the secondary (or in LSST's case, tertiary) mirrors. *Astronomy*: Kellie Jaeger

week to observe the entire visible night sky. And LSST will cover about 20,000 square degrees — the entire sky visible at any one time — in about 3 days once its full operations begin in 2017.

A large field of view requires a huge camera, and both Pan-STARRS and LSST deliver. Each telescope in the Pan-STARRS array will have a 1.4-billion-pixel camera. The array of CCD detectors measures 16 inches (40 centimeters) on each side. The first Pan-STARRS telescope began regular observing in March 2009. This scope, called Pan-STARRS 1, serves as the prototype for the other three. They each will have a very similar massive camera and similar telescope technology.

In fall 2009, the Pan-STARRS team stopped operations because the scope was having problems focusing. The scientists determined that parts of the support system maintaining the position and alignment of the mirrors to extreme precision weren't working properly. But by early 2010, the defective parts were redesigned and Pan-STARRS 1 was again taking data. PS1 will observe each piece of sky visible from Hawaii 12 times in each of five different color filters.

The prototype telescope helps find and fix problems before the entire system is operational. "We are continuing to make incremental improvements to the PS1 system as time goes on, and we will certainly incorporate such design changes in the designs of the subsequent Pan-STARRS telescopes," says Jeff Morgan of the University of Hawaii.

The LSST project is a bit further in the future, but once online in 2017, its whopping 3.2-billion-pixel camera will be the largest digital camera ever constructed. The entire camera system will be 5.2 feet by 9.8 feet (1.6 meters by 3m), while the detector itself will measure 25 inches (64cm) in diameter.

Tiling the sky

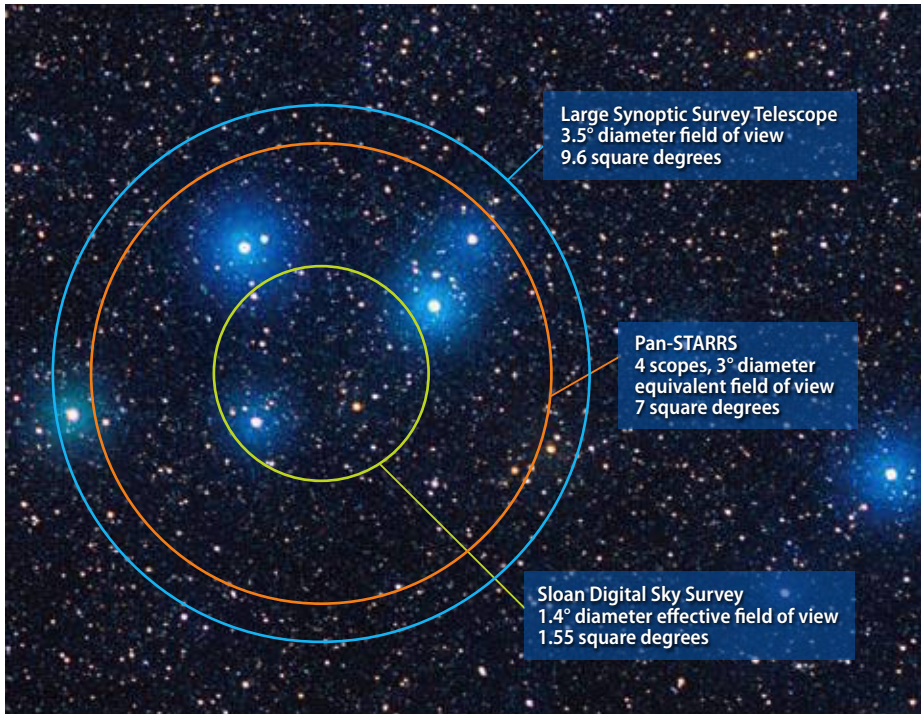
LSST Director Tony Tyson says, "LSST will create an SDSS volume of data every night" — about 10,000 square degrees and 15 terabytes of data. Over LSST's 10-year operation, researchers are looking at 60 petabytes of data — a 6 followed by 16 zeros. LSST's catalogs will hold information on 10 billion stars and 10 billion galaxies. For comparison, SDSS's catalogs cover 350 million celestial objects.

So how will scientists manage the flood of data that comes from these projects? Advances in computing make these surveys possible. Project scientists are quick to discuss "Moore's law," which says that computing power doubles roughly every 2 years, so these telescopes should stay on track.

Both LSST and Pan-STARRS will visit a sky location and then move to the next, essentially "tiling" the sky. Each project's "visit," however, will vary in length. Determining the exposure length comes down to a balance of two factors: It must be long enough to determine what's electronic noise and what's sky data, but short enough that asteroids and other moving objects don't smear.

At each patch of sky, Pan-STARRS will snap a 30-second exposure that reaches down to 24th magnitude. Then it will move to the next spot while downloading the data. The project will continue this process around the entire visible night sky, three times each month.

The scope will come back to image the same patch of sky within a few tens of minutes to a few weeks. It depends on the region. This technique helps identify main-belt asteroids — too long an interval



Astronomy: Kellie Jaeger; Photograph: Bill and Sally Fletcher

A wide field of view is crucial for a survey telescope. Here's how the effective imaging fields of SDSS, Pan-STARRS, and LSST compare on a 6°-wide area of the constellation Delphinus.

By the numbers

Pan-STARRS

Primary mirror: four 1.8-meter mirrors acting together
Effective aperture: 3.6 meters
Field of view: 7 square degrees
Square degrees per night: 6,000 square degrees
Camera size: 1.4 billion pixels
Exposure length: 30 seconds
Magnitude in one exposure: 24
Magnitude in stacked exposures: 26
Full operations goal: 2013
Nightly raw data: 3 to 10 terabytes
Location: Mauna Kea, Hawaii
Survey lifetime: 10 years

and the asteroid may move too much for Pan-STARRS's brain to identify it as the same object. According to Pan-STARRS researchers, Kuiper Belt objects (KBOs) need a bit more time — say, days. And variable star observations will depend on the star's pulsation period.

LSST will take a slightly different approach. It will visit one patch of sky and snap two consecutive 15-second exposures. Then, like Pan-STARRS, it will download data while moving to the next patch. Through this process, LSST will image each spot in its 20,000-square-degree sky survey 2,000 times over the telescope's 10-year survey lifetime. The telescope will essentially create a flipbook of each 9.6-square-degree tile of sky. LSST's brain will monitor differences from one image to the next.

Searches for moving, changing, and transient objects are key research areas for both projects. With the massive amount of collected data, each telescope's software will compare subsequent images. To find moving or transient objects, the second image will be subtracted from the first, revealing noise and any changes in object brightness or position.

Each scope's supercomputer brain can detect things with brightness changes (like supernovae and gamma-ray bursts) or things with positional changes (like asteroids, comets, and KBOs). "To detect things that move — like asteroids, for example — you have to take some exposures now ... and then you have to revisit that same patch of sky to pick that guy up again within about an hour," explains Tyson. "And then you have to do it again tomorrow night. And then you have to do it again next week, etc." Once the LSST's brain determines something is different, it will send out an alert — within 1 minute — to scientists and amateur astronomers.

The first Pan-STARRS telescope saw first light in 2006. It began operations in March 2009 and has since discovered nine supernovae and seven asteroids, in addition to detecting another 4,000 already-known asteroids. Brett Simison

Celestial object census

In 1994, Congress directed NASA to work with other space agencies and the Department of Defense to document 90 percent of comets and asteroids 0.6 mile (1 kilometer) and larger whose orbits cross Earth's. In 2005, Congress updated this goal to 90 percent of near-Earth objects (NEOs) larger than 460 feet (140m) by 2020. Current technology can't reach this goal, but wide-field surveys can.

Pan-STARRS will look for objects about 100 times fainter than current NEO surveys can detect. Researchers with Pan-STARRS estimate that the project will catalog some 10 million main-belt asteroids and tens of thousands of NEOs and KBOs. They expect the project will complete the survey of all 0.6 mile (1 km) NEOs and document most of those down to 980 feet (300m).

And after LSST comes online several years later, it will reach the requirement. Computational modeling by LSST scientists implies that the telescope can find 90 percent of those potentially hazardous asteroids larger than 460 feet (140m).

NEOs aren't the only solar system objects the future projects will search for.

In early 2008, while debugging the first Pan-STARRS telescope and its camera, the team imaged the Whirlpool Galaxy (M51). Image quality has since doubled, which eliminates artifacts such as the stripes. Pan-STARRS/University of Hawaii

Both telescopes anticipate finding tens of thousands of KBOs. They might even detect Mars-sized objects in the region past Neptune.

Both LSST and Pan-STARRS will look for supernovae, gamma-ray bursts (GRBs), and other such cosmic flares. Astronomers anticipate that each month Pan-STARRS will discover and analyze about 5,000 type Ia supernovae — the kind scientists used in the late 1990s to discover that the universe's expansion is speeding up. LSST is expected to find about a million such supernovae. These detections will add greatly needed data to the few hundred type Ia supernovae that cosmologists currently analyze.

GRBs are even more powerful than supernovae; they are the most energetic blasts known and signify violent deaths of massive stars. While a GRB's initial explosion emits gamma rays and X-rays, afterglow radiation in lower energies follows this high-energy emission. Both telescopes will capture the visible-light afterglow of GRBs. And these are just a few examples of the changing objects that researchers with both Pan-STARRS and LSST hope to hunt during the wide-field surveys.

Some of this science will occur in "deep-drilling programs," where LSST will analyze about 40 or 50 selected fields over its 10 years. The telescope will take a lot of fast exposures in each of the selected fields and then stack them. This is an ideal way to find objects that change on rapid timescales. It's also a good way to find faint objects, such as those in the Kuiper Belt. In fact, a couple of these fields will be near the ecliptic specifically to find KBOs.

Cosmological questions

In 1998, Roger Angel of the University of Arizona's Steward Observatory Mirror Lab suggested to Tyson a three-mirror optical design that might be used for his proposed telescope to study dark matter. Ten years later, scientists and engineers cast and began polishing the 8.4-meter primary mirror of that suggested scope. But it isn't just for dark matter research anymore. Instead, researchers recognized that the technology involved in this "dark matter telescope" could also help discover near-Earth asteroids and other transient objects. They renamed it LSST.

The project will have a big influence in cosmology research. Scientific evidence points toward our universe being mostly "dark." Researchers can detect the majority of the cosmic mass via only the gravitational force. In addition, the universe's gravitational pull seems to be losing out to some mysterious force, letting cosmic expansion speed up. Scientists aren't sure why or how (or even if they're reading the evidence correctly), but LSST observations should help.

LSST will use four different cosmological probes to explore dark energy and dark matter. Through its all-sky survey, the telescope will detect billions of galaxies and more massive structures in the present universe back to half of the universe's current age. As light from a galaxy passes near a massive object (such as a galaxy cluster), the massive object bends the light. This effect is called gravitational lensing. LSST sees the effect of a foreground object warping a background galaxy's light. So, the more distant a galaxy is, the more warped its image will be. When LSST moni-

LSST will use a special mirror design to achieve a 9.6-square-degree field of view. This will allow the telescope to observe the entire available sky in 3 days. LSST Corporation

By the numbers

LSST

Primary mirror: 8.4 meters
Effective aperture: 6.7 meters
Field of view: 9.6 square degrees
Square degrees per night: 9,000 square degrees
Camera size: 3.2 billion pixels
Exposure length: 15 seconds
Magnitude in one exposure: 24
Magnitude in stacked exposures: 27.7
Full operations goal: 2017
Nightly raw data: 15 terabytes
Location: Cerro Pachón, Chile
Survey lifetime: 10 years

Over two days in March 2008, engineers at the University of Arizona's Steward Observatory Mirror Lab loaded 51,900 pounds (23,500 kilograms) of glass into the LSST's primary mirror mold. Engineers are now polishing the 8.4-meter mirror. Ray Bertram/Steward Observatory

tors the sky, it will find a sea of this "weak" gravitational lensing.

For each galaxy, LSST will measure warp and six colors (color provides a distance measurement) to create a map of the universe's mass. Because dark energy affects how cosmic structures grow and how the distances between such structures change, knowing the universe's mass distribution will provide cosmologists clues about dark energy's properties.

Weak gravitational lensing is just one way that scientists will use LSST to answer questions about the universe. Because cosmological research is a main purpose of the telescope, you can bet scientists will use much of LSST's 10-year survey data to analyze such conundrums.

While Pan-STARRS's main focus will be on NEOs and other solar system objects, it too will contribute to cosmological finds. "The beauty of a wide-field survey system is that all data are available for research purposes," explains Pan-STARRS project manager William Burgett. So, scientists can use the gathered data for weak gravitational lensing research in addition to asteroid searches.

Not just for the pros

Like SDSS, Pan-STARRS and LSST will release huge datasets for the scientific community and the public to explore. Astronomers can use the data to look for near-Earth asteroids, variable stars, supernovae, and other transient objects — many as-of-yet undetected. Cosmologists can use the data to analyze the properties of dark matter and dark energy.

But LSST goes even further. People won't have to wait until the official dataset release. Instead, everyone — scientists in other collaborations, educators, middle school students, amateur astronomers — also will have complete access to the data almost as soon as it's collected.

As Tyson explains, "LSST is an open-source, open-data project." This type of open-source is the future of astronomy, and, he adds, it's the future of many fields.

Future, yes; unobtainable, hardly. LSST's mirrors have already been cast. The camera technology is right on track. The biggest hurdle is the software. "It's one thing to dump petabytes onto the floor and say, 'Come and get them,' " explains Tyson. "It's another to deliver up accurately calibrated and trustable products (a range of them), and then make the data accessible in a friendly way so that scientists can do calculations, and everybody can get their hands on this data. Curious minds of all ages can ... explore the universe on their own."

Also extraordinarily computationally demanding, the full Pan-STARRS array will be operational in a few years — members are hoping in about 3. It will make great strides in finding and cataloging solar system objects and showing that such deep wide-field technology works extraordinarily well. Then a few years later, LSST will gather deeper data with its larger collecting area. Together, these future projects will transform how researchers do astronomy.

How weak gravitational lensing works

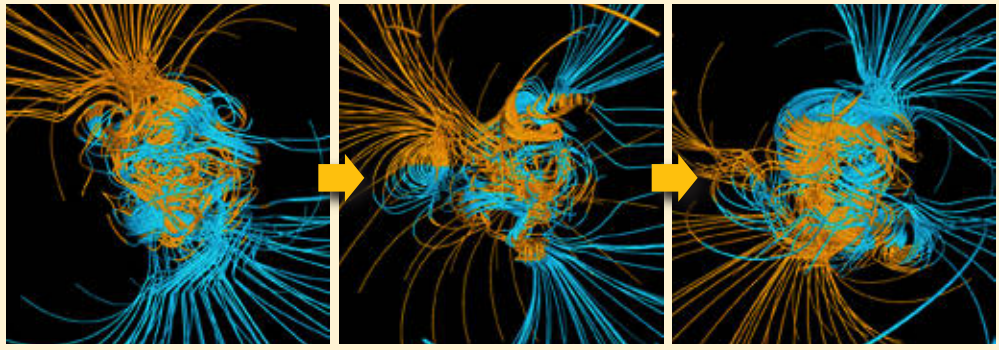
If foreground galaxies get in the way of light from more distant galaxies, that light will bend slightly because of the intervening mass. This creates a slight warp in images of individual galaxies. Analyzing this warp can help scientists map mass distribution. LSST Corporation

Ask Astro

Astronomy's *experts from around the globe answer your cosmic questions.*

Have Earth's poles flipped?

Q: Is there any evidence that Earth's magnetic poles (or any other planet's) have reversed? What would cause such a reversal? — **Gerhard Ligon,** Cary, North Carolina



Earth's magnetic field reverses over a little more than 1,000 years in this simulation. Blue field lines are directed inward, and yellow are directed outward. Gary Glatzmaier

A: There certainly is evidence of magnetic dipole reversals of Earth's magnetic field. In the middle of the 20th century, ships recording the magnetic field in the ocean floor found stripes of reversed magnetic polarity between stripes of normal magnetic polarity at the Mid-Atlantic Ridge. This suggests that as the Atlantic Ocean slowly spreads apart and new hot floor material emerges from the ridge, the current magnetic field polarity (i.e., north- or south-directed magnetic field) gets recorded in the new ocean floor when it cools. This discovery was one of the major arguments in favor of the theory of continental drift. Scientists have also measured magnetic reversals in lava flows that slowly cool, and in the sediments in lake and ocean bottoms.

The flow of electrically conducting fluids within planets and stars (for example, liquid iron in Earth's core and ionized hydrogen in the Sun) maintains a magnetic field. Convection drives the flow, and the rotation of the planet or star influences the flow pattern. Exactly how this happens is an ongoing focus of research. Scientists now study fluid flow mostly with computer simulations. Within the past 15 years, several groups around the world have seen dipole reversals occur in their simulations.

The time between reversals in Earth is highly irregular, ranging from tens of thousands to tens of millions of years, with a rough average of 200,000 years. Each reversal's duration also varies, with an average of about 5,000 years. The last time Earth reversed its polarity was about 780,000 years ago. The Sun is much more regular: Its magnetic dipole polarity reverses every 11 years.

Mercury has a magnetic field, and Mars used to have one. All four of our giant planets have fields. But we have not observed a reversal on another planet. — **Gary Glatzmaier,** University of California, Santa Cruz

MOVING THE MOON

Q: The current theory of lunar genesis says a Mars-sized object collided with the nascent Earth and ejected material that later coalesced into the Moon. Is it just by chance that the newly formed Moon adopted an orbit that coincides with the ecliptic plane? — **David Nunley,** Columbus, Ohio

A: Assuming that the collision happened as we believe, **the cloud of debris would have quickly concentrated into a ring over the equator, allowing the Moon to have formed close to Earth in an equatorial orbit.** Tidal forces, however, forced it to move outward, rapidly at the beginning and then more slowly at greater distance. That means the Moon has been at such a large distance for so long that **the gravitational forces of the Sun and Earth factor into the orbit's geometry.**

The orbit has changed to a plane similar to that of the ecliptic. Technically, the Moon's orbit is in a sort of gravitational compromise between Earth forces and solar forces, called a "Laplacian plane." If it were exactly in the ecliptic plane, we'd have eclipses every month. Instead, the Laplacian plane precesses with an 18-year period, which produces more complex eclipse cycles. — **William K. Hartmann,** Planetary Science Institute, Tucson, Arizona

STARS ON PARADE

Q: Is every star in a designated galaxy? Are there any "rogue" stars? — **Billy Finch,** Silver Spring, Maryland

A: While all stars must at least have parent galaxies, a tiny number manage to escape and enter intergalactic space. Stars are born from clouds of interstellar gas and dust when embedded cloudlets contract under the force of their own gravity. The only place where the clouds are dense enough for this to happen is within the confines of galaxies, which is also where we find sufficient compression mechanisms, such as supernova shock waves.

The parent galaxy's gravity traps the vast majority of stars. They serve out their lives orbiting their galactic centers. On occasion, a star can gravitationally interact with another object and be accelerated past its parent galaxy's escape velocity. Indeed, we do find such intergalactic wanderers. Collisions between galaxies in galaxy clusters can also do the job.

Other mechanisms that can fling out stars are off-center explosions in supernovae, which can send the resulting neutron stars off at high speeds; gravitational interactions among binary stars; and supernovae in double-star systems in which the companions are kicked away. (However, the latter two are probably not energetic enough to kick stars completely out of the galaxy's grip.) Even if a star does escape, it must trace its lineage back to some originating galaxy. **— Jim Kaler,** University of Illinois, Urbana-Champaign

One of the most colorful images taken of the Moon, this NASA compilation shows shades of green and brown in addition to gray. NASA

SHADES OF GRAY

Q: Why are all moon photos in black and white, and yet other planets show color? —David Winckle, Caloundra, Australia

A: Many Moon photos are actually color images! Unfortunately, unlike the planets, the Moon's surface has no brightly colored areas. Most of its color is a mix of dark browns, grays, or black. In fact, although the Moon (especially when it's full) appears bright, it reflects only 7 percent of the light that falls on it. That's the equivalent of a freshly paved blacktop highway. Although the Moon appears in photos and to our eyes as a lighter shade (tan, yellow, or even white), its surface is quite dark.

The exception to the Moon's lack of color comes during the total phases of lunar eclipses. When Earth's dark inner shadow fully covers the Moon, our planet's atmosphere bends sunlight onto the Moon's surface. Depending on how clean our air is at the time, the Moon during totality can appear yellow, orange, copper, tan, red, brown, or any combination thereof. Or, if the atmosphere contains lots of particulates, like after a large volcanic eruption, the Moon can nearly disappear during the total phase. That's quite a sight! **— Michael E. Bakich,** Senior Editor

How does Venus' day compare with its year? Visit www.Astronomy.com/toc to find out.

ANDROMEDA-MILKY WAY MERGER

Q: Even though we won't be around when M31 approaches, what will be the earliest effects of the collision on Earth, the Sun, and the solar system's planets? — George E. Laird, Ft. Myers, Florida

A: The earliest effect of the collision between the Milky Way and the Andromeda galaxies would be a change in the night sky. Currently, the bright disk of stars in Andromeda occupies roughly 3° on the sky (the Full Moon's diameter is ½°). Within 2 billion years, the Andromeda Galaxy will grow bigger by an order of magnitude, covering a region as big as the entire path of the Milky Way (but with a different orientation) in the night sky. Tidal forces during the interaction of the two galaxies would tear away star streams — offering a spectacular view of elongated tails.

Within 5 billion years, the two galaxies will make one big elliptical galaxy, which I call "Milkomeda." **Compared with today's view, where the Milky Way disk appears as a strip of stars stretching across the night sky, Milkomeda's stars will be scattered all over the sky.**

Next, the collision will kick the Sun away from its current location of 26,000 light-years from the Milky Way's center. T. J. Cox and I performed numerical simulations indicating that the Sun will most likely be scattered to a distance that is a few times farther than that from the center of Milkomeda.

The chance that a star would pass sufficiently close to disturb planetary orbits is extremely small. In our immediate vicinity, the evolution of the Sun (whose remaining lifetime is comparable to the merger timescale of 5 billion years) will influence life on Earth more than the merger between the Milky Way and Andromeda. **— Avi Loeb,** Harvard University, Cambridge, Massachusetts

Send your questions via e-mail to: **askastro@astronomy.com**; or write to **Ask Astro, P. O. Box 1612, Waukesha, WI, 53187.** Be sure to tell us your full name and where you live. Unfortunately, we cannot answer all questions submitted.

A famous telescope turns 40

Bart Bok was a proponent of educating students about astronomy. He'd be happy to know that the telescope that bears his name is now used for both research and education.

by Don McCarthy and David H. Levy

In June 1969, after inspecting a photographic plate of globular cluster M13, then director of the University of Arizona's Steward Observatory Bart Bok enthusiastically announced, "Well, gentlemen, we have a telescope!" His statement declared the seventh-largest telescope in the world (at that time) operational. Forty years later, in 2009, the late Bok would have been thrilled to see teenagers from around the world using the same 90-inch instrument — now named the Bok Telescope — during the International Year of Astronomy.

Bok (1906–1983) taught at Harvard University for 28 years, but had to leave during the anti-communist purge of the 1950s. He went halfway around the world to build a great observatory in Australia; some years later he returned to the United States to repeat the achievement with Steward Observatory. There, a planned 60-inch scope became a 90-inch. When Bok spoke with Lee Hayworth, then head of the National Science Foundation, regarding a proposal for a new telescope at Kitt Peak, Hayworth responded: "Bart, you know how to build observatories. You know how to run observatories. I'm going to turn the '6' upside down to a '9' and give Steward Observatory a 90-inch."

Despite Bok's international reputation as a researcher of the Milky Way and as a proponent of new technologies, he believed strongly in teamwork and in inspiring young people to reach for the stars. In the latter, he was ahead of his time and would have encouraged the use of his telescope for science education. This is precisely what the annual teenager Astronomy Camp programs do. Last summer, the camp brought some 50 students to live and work on Kitt Peak.

Educate the future

Since 1988, Astronomy Camp has engaged students ages 11 to 85 in the process of hands-on observation and research using modern observatory facilities. While most programs use the equipment at Mount Lemmon, near Tucson, Arizona, the teen camps in 2009 used facilities at Kitt Peak. Many of the camp's staff members were once campers themselves and enjoy returning annually to inspire new students.

In 2009, during the weeklong Beginning and Advanced Teen Camps, 27 boys and 23 girls attended from 16 states, Spain, India, and Honduras. A few students were from the Tohono O'odham Nation of Native Americans, which has leased the Kitt Peak summit to the United States government for astronomy and education since 1958.

Bok was passionate about inspiring future astronomers. "Astronomers have responsibilities to attract promising young students into the profession," he said, "and we should make special efforts to show them the fine opportunities that lie ahead." An experience like Astronomy Camp highlights authentic inquiry with a youth-centered, personal approach, and treats youth as colleagues rather than children. So, it's fitting that the Advanced Campers used the Bok Telescope throughout the week for astronomical research. The students used the original spectrometer, now equipped with a CCD detector, to research topics relating to comets, star formation, planetary nebulae, and galaxies.

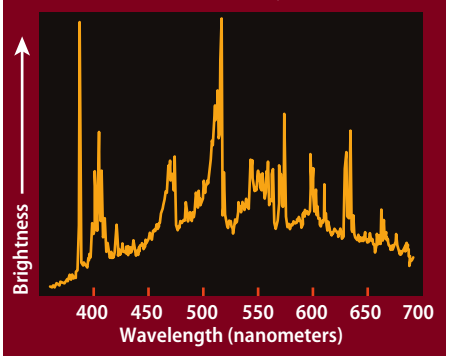
A night's observations

Bok had a special approach to observing that kept him focused and levelheaded: "When you are in an observatory at three o'clock in the morning, stop your photograph. Stop your photometer. Walk away from the telescope. Walk down the stairs. Walk out the front door. Now walk 20 paces — no more, no less. Then stop — and look up at the sky — just to make sure you are making bloody sense." So, during the camp on June 23, 2009, participants took a break from pure research for some eyepiece observing and to commemorate the 40th anniversary of the telescope's dedication.

AIP Emilio Segre Visual Archives

Bart Jan Bok, a prominent astronomer in the mid-1900s, would likely be happy to see the telescope with his namesake being used for astronomy education and outreach.

A comet's analysis



Advanced Astronomy Camp students analyze the characteristic light that an astronomical object emits, called a spectrum. The students obtained this spectrum of Comet C/2009 P1 Garradd June 23, 2009.

Astronomy: Kellie Jaeger after Anonymous

Don McCarthy *is an astronomer at the University of Arizona and the director of Astronomy Camp.*
David H. Levy *is an* Astronomy *columnist.*

That night, David and Wendee Levy led the celebration. As Bok's biographer, David recounted stories of the telescope's "first light." For the observation of the M13 star cluster back then, researchers had to point it in declination by hand using ropes. Now, 40 years later, the entire group observed M13 again (but with computerized equipment), as well as Saturn.

While waiting for their turns at the eyepiece, campers assembled a few meters away on the outdoor "Bok Walk." In the words of camper Bobby Shely: "… the night was just an aspiring astronomer's dream come true — spending the night looking through a gigantic telescope at whatever we decided to point it at. When I wasn't looking through the 90-inch, I was on the Bok Walk, doing exactly what Bart Bok intended it for — taking a moment to just look up at the sky with your own two eyes and admire the sheer beauty of the stars."

At 9:21 P.M., screams and loud cheering erupted as a magnificent fireball meteor crossed the sky over the McMath-Pierce solar telescope to the southeast and cast shadows on the other domes as it exploded in the eastern sky about 70 miles away near Wilcox, Arizona. Student Ian Godwin recalls: "I saw it start from the corner of my eye, white, around 65–70 degrees at south-southeast. I turned to see it. By this time, it had turned kind of greenish-blue and was about 50° southeast. It exploded about 40° east-southeast, and about 6 pieces continued to fall until they faded out around 20° above the horizon, just south of the edge of Tucson. I do remember a kind of crackling sound, which I thought was impossible. … "

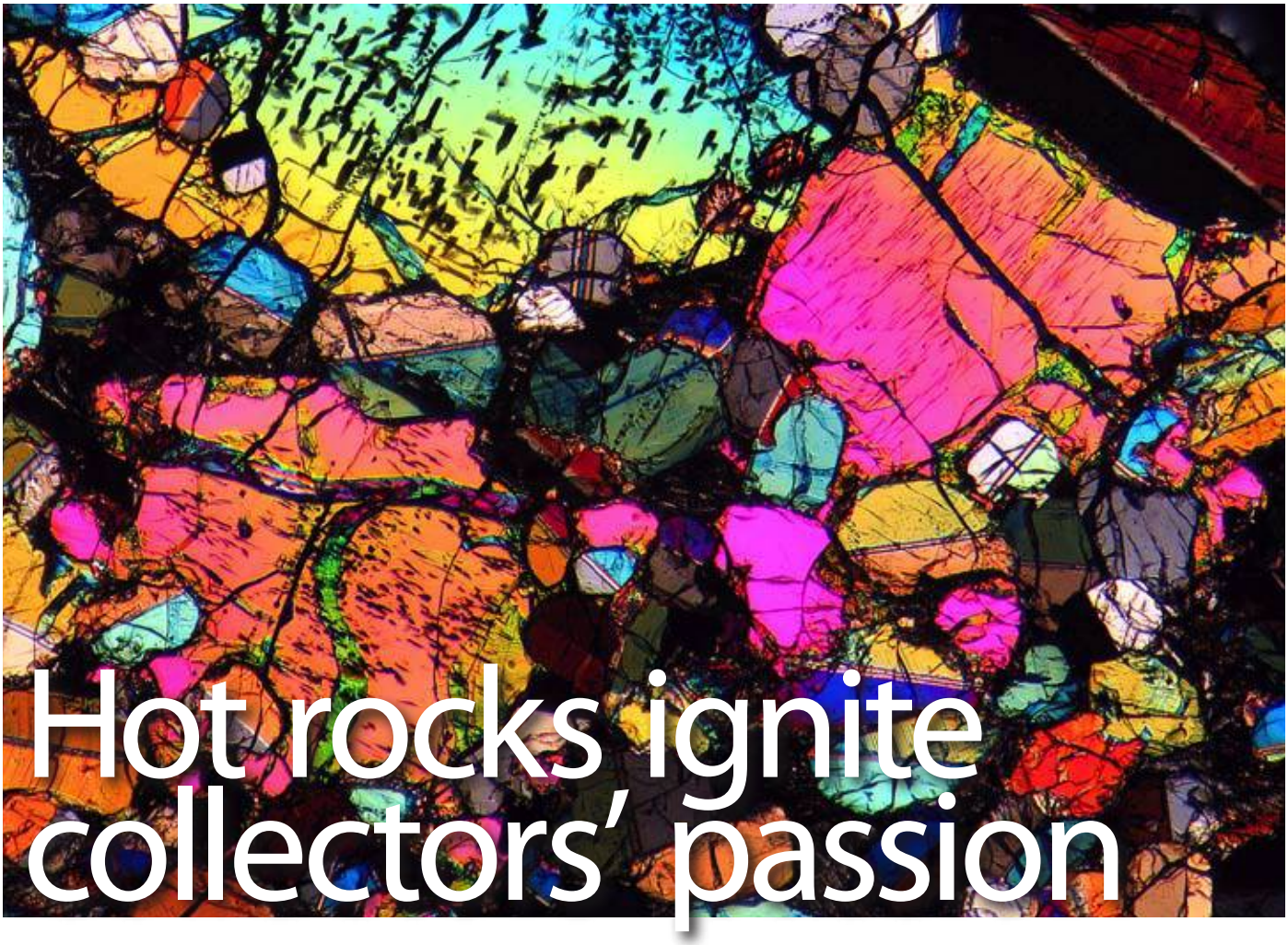
This fireball produced the first known "falls" of meteoritic material in Arizona since 1912. To date, researchers have recovered about 10 pieces of chondritic stones. After analyzing numerous eyewitness reports, Carl Hergenrother of the University of Arizona's Lunar and Planetary Laboratory has suggested that this event might have been part of a previously suspected meteor shower (the "Corvids") moving at slow speed, about 7 to 11 miles/second (11 to 17 kilometers/second). Campers certainly will look for more meteors in the summer of 2010.

Still under the influence of the spectacular fireball, campers returned to the "Bok computer" to continue their CCD spectroscopy projects. They interrupted their work on extragalactic objects to observe Comet C/2009 P1 Garradd, whose spectrum revealed a complexity of interesting emission lines.

No doubt, Bok would be very happy and proud of the campers' observations and research projects. Were he to gaze upon the teenage students he never met, he would indeed have said, "We still have a telescope."

The 90-inch Bart Bok Telescope just passed its 40th anniversary as a research and education tool under the Arizona skies. David A. Harvey

Read how Bart Bok became interested in astronomy at www.Astronomy.com/toc.



Hot rocks ignite collectors' passion

Anne Black/Impactika

At the Tucson Gem and Mineral Show, leading meteorite dealers display spectacular new finds and old, treasured favorites.

by David J. Eicher

This thin section is from the Nakhla martian meteorite. Researchers view thin sections through a polarizing petrographic microscope. The colors show the minerals in the specimen. Impactika sells many meteorite thin sections.

Once a year, an event takes place that brings together everyone who cares about space rocks. It's the Tucson Gem and Mineral Show, and for more than 50 years the event has attracted collectors, dealers, writers, and enthusiasts. Areas of interest include minerals, gems, beads, jewelry, and — yes — meteorites.

This year I went to the show mainly to interview several meteorite dealers about the current happenings in meteorite collecting. What I came away with were some amazing finds, great images, video interviews, and indications of a thriving hobby-within-a-hobby.

Why collect rocks from space? Well, so much in astronomy happens on such large distance scales that we hold most of our treasured moments as ethereal: a great view of the Orion Nebula or memories of a spectacular auroral display. With meteorites, however, you can actually hold tangible stuff in your hands.

You can handle a piece of the asteroid 4 Vesta. You can hold a piece of the Murchison stone meteorite, a revolutionary discovery rich with amino acids. You can touch a carbonaceous chondrite that originated in the outer solar system. Such objects predate the existence of the planet you are standing on.

Meteorites let you feel astronomy as a subject. And with a quest for the most exciting stuff currently out there, I set off for Tucson and its great show — actually a network of many overlapping shows — with John Eicher, my dad, who is a chemist and mineral enthusiast. We traversed hundreds of dealers looking for interesting rocks in early February. Little did we know what was in store for us.

Here come the Meteorite Men

Perhaps the most outspoken characters in the meteorite field right now are Geoff Notkin of Aerolite Meteorites (www.aerolite.org) and his partner Steve Arnold

The Sikhote-Alin meteorite fall occurred around 10:30 A.M. February 12, 1947, in a remote region of the Primorye Province in Russia. The main characteristic of pristine specimens is a ragged, almost torn, appearance. Geoffrey Notkin and Steve Arnold exhibited numerous fine pieces at the Tucson Gem and Mineral Show. Geoffrey Notkin

(www.stevearnoldmeteorites.com). You may know them as TV's *Meteorite Men* from the series of the same name on the Science Channel. This year, the popular series has focused on such interesting localities as Odessa, Texas; Gold Basin, Arizona; Ash Creek, Texas; and Buzzard Coulee, Canada. For more on the series, see www.meteoritemen.com.

"Finding meteorites is only part of the challenge," says Arnold. "The other challenge is finding a home for them after we've found them." Some specimens go to researchers and some to private collectors, Arnold explains, and it's these meteorites that rock hounds go crazy for. I caught up with Arnold and Notkin at the Hotel Tucson City Center, where they displayed many dozens of their treasures and held court with fellow collectors.

Notkin displayed a beautiful, huge slice of the Brenham, Kansas, pallasite — a million-dollar rock — that Arnold famously found the main mass of in 2005. This find served as the pilot episode of *Meteorite Men* as well. The slice they displayed was from one of Arnold's larger finds. The specimen is beautiful because of the included olivine crystals in the nickel-iron matrix that makes up most of the meteorite's weight.

Another spectacular piece Notkin showed was a hand-sized Sikhote-Alin iron meteorite from the famous Russian fall in 1947. Although Sikhote-Alin meteorites are common because searchers recovered a huge quantity (the largest of any recorded fall), the piece Notkin displayed had extraordinary sculptural details from the melting of the metal as it heated in Earth's atmosphere and tumbled to the ground.

Arnold then showed an incredible slice of the Gibeon iron meteorite, another massive fall from Namibia. He and Notkin call it the "chili pepper" because of its fantastic shape. The piece also displays a terrific Widmanstätten pattern made visible by cutting, polishing, and etching the piece with a mild acid. The pattern is unique to iron meteorites, revealing the crystallization of the metal over long time periods of gradual cooling — something that didn't occur on Earth.

The men next displayed a piece of the Canyon Diablo meteorite collected at Meteor Crater near Winslow, Arizona. Aside from being a quite large, sculptural specimen, this sample stands out because the legendary meteorite collector Harvey H. Nininger collected it, probably in the 1940s or '50s. Such a provenance, linked to one of the great figures of meteoritics, makes this iron a real gem in the world of meteorite collecting.

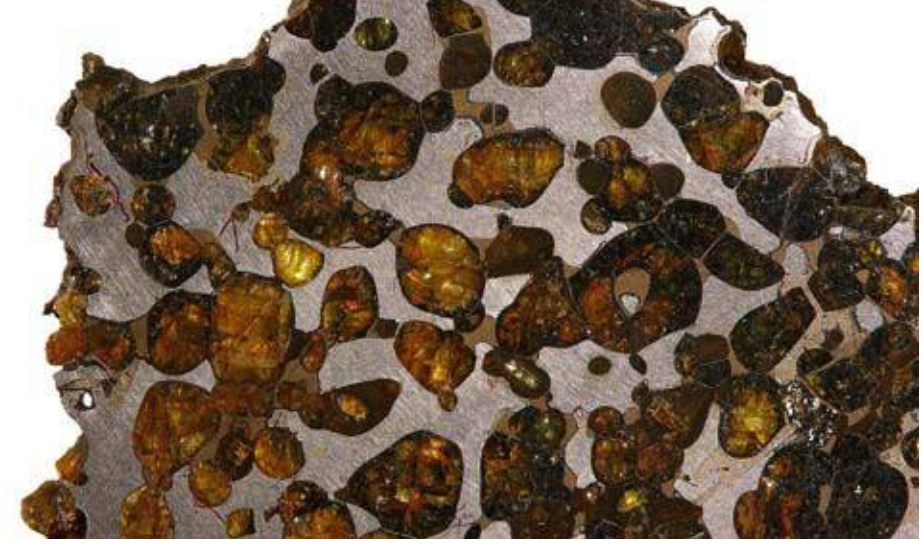
One of the most famous historical meteorite falls occurred in Ensisheim, Alsace (now part of France) in 1492. "It is one of the oldest known meteorite falls," Notkin says. "It fell on November 7, 1492, when even Arnold was a young lad." He adds, regarding the piece they had on display: "You can see amazing brecciation there, where different elements were forced together."

Northwest Africa (NWA) 5000 is a lunar meteorite searchers found in southern Morocco in July 2007. Anne Black of Impactika Meteorites sells specimens of this achondrite for as little as $200. The total collected weight of this meteorite was 25.4 pounds (11.5 kg). Anne Black/Impactika

After showing one of the oldest known falls, the men brought out specimens from one of the newest falls, Buzzard Coulee, from Saskatchewan, a chondrite that fell November 20, 2008. Their specimens showed a glistening black fusion crust that looked like it formed yesterday. As they held those stones and talked about roaming the Canadian fields just last year, the enthusiasm Notkin and Arnold bring to their work filled the room — these are two happy campers who contribute a great deal to the hobby of meteorite collecting.

What makes these Canyon Diablo meteorites special is that famed American meteorite collector and dealer Harvey H. Nininger (1887–1986) collected them. Canyon Diablo meteorites originated in the blast that created Meteor Crater near Winslow, Arizona. Geoffrey Notkin

David J. Eicher *is the editor of* Astronomy. *He has collected meteorites since astronomy writer Walter Scott Houston gave him one in 1978.*



The Brenham fall, a site near Haviland, Kansas, first yielded pallasites in 1949. While searching the region in October 2005, Steve Arnold discovered the main mass — a 1,433-pound (650 kilograms) monster valued at $1 million. This picture shows a slice of the Brenham pallasite. Geoffrey Notkin

France is heard from …

Sharing the same room at the Tucson show with Arnold and Notkin was another energetic soul in the meteorite world, Anne Black of Impactika Meteorites (www.impactika.com). A native of France and now calling the Denver area home, Black harbors one of the great collections any dealer can currently show.

Aside from her beautiful display specimens, Black has what is probably the largest collection of meteorite thin sections in the world, some 600 altogether, in a neat cabinet. Thin sections are slices of meteorite samples that scientists study microscopically. With transmitted light, thin sections can reveal textures and crystallization patterns, whereas polarized light shows a wash of colors that allow mineral identifications.

In her normal stock of miniature and cabinet-sized specimens, Black specializes in historical meteorite falls — "meteorites with a pedigree," as she puts it. One of the meteorites Black pulled off the shelf to show us was a slice of Clark County, Kentucky, a 63.7-gram iron octahedrite valued at $2,100 from the find in 1937. As she walked about the room, numerous other historically important meteorites, many of which you can find on her web site, surrounded Black.

Mineral collectors are familiar with a colleague of Black, the French dealer Alain Carion, one of the world's experts on meteorites. He's also the proprietor of a superb shop handling meteorites and minerals in Paris, not far from the Cathédrale Notre Dame. Carion has just produced a second edition of his famous introductory guide, *Meteorites*, which Black translated into English. This terrific book is available on the Impactika web site for $20 plus postage and ought to be a cornerstone text in any meteorite collector's library.

In one corner of Black's room was a display of several slices of NWA 5000, a fantastic lunar meteorite found in Morocco in 2007. She offers pieces of this Moon rock for as little as $200 and as much as several thousand each, for those of you who really want to hang a piece of the Moon on your wall.

Another happy Frenchman …

A few doors and one floor down from the Meteorite Men, I encountered another famous French meteorite hunter, Luc Labenne of Labenne Meteorites (www.meteorites.tv). Labenne has been hunting and dealing meteorites for many years and is known for his high-end specimens that often end up in museum collections. The inventory on his web site shows a wide range of diverse stones, irons, and stony-irons of all sizes and values.

Labenne proudly displayed two new lunar meteorites, the first of which — Dhofar 1528 — is an achondrite he found in the desert in Oman in June 2009. Labenne displayed the main mass of this stone, a 72.3g piece that showed rich brecciation with five or six different kinds of rock. The reverse side showed a rough, wind-blasted appearance. In a different display case, Labenne showed another new lunar, Dhofar 1527, this one found by his brother Jim in March 2009, also in the desert in Oman. This stone may well be from the lunar farside.

Another rare lunar meteorite, Shisr 166, also fell in the desert in Oman, and searchers found it in the spring of 2008.

The Clark County meteorite is an iron octahedrite found in Kentucky's Clark County in 1937. Most of the 26-pound (11.8 kg) mass became part of the American Meteorite Laboratory collection administered by Harvey H. Nininger. This specimen offered by Impactika weighs 63.7 grams. Anne Black/Impactika

ITQIY (yes, that's really its name) is a primitive, enstatite achondrite that fell in Western Sahara around 1990. At that time, a nomad found a 410-gram piece. Luc Labenne, while on an expedition to hunt meteorites in 2000, found a 9.5-pound (4.3 kilograms) specimen of this stone meteorite. Luc Labenne

This meteorite doesn't even have a name yet. Perhaps meteoriticists will dub it Minera Escondida, a large copper mine near the discovery site. Luc Labenne found it during a meteorite-hunting trip to Chile in 2004. Scientists classify it as a carbonaceous chondrite bencubbinite, an iron meteorite with many inclusions. Luc Labenne

The Buzzard Coulee fall occurred November 20, 2008, in Saskatchewan. In 2009, Geoffrey Notkin found several pieces of the meteorite while searching the strewn field with a strong magnet affixed to a walking stick. Geoffrey Notkin

Dhofar 1528 is a recently discovered lunar meteorite, the main mass of which weighs 72.3 grams. This anorthosite originated in the lunar highlands. Meteorite dealer Luc Labenne found this specimen silhouetted against the Oman desert in June 2009. Luc Labenne

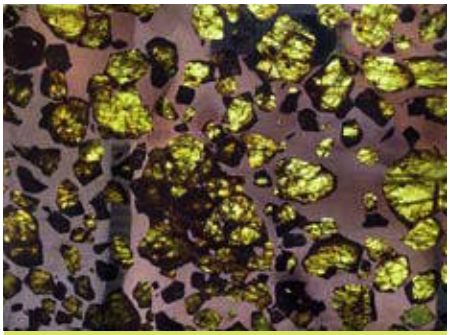
Labenne displayed a beautiful 4g piece that, amazingly, he found at night! In contrast to the two Dhofar specimens, Shisr 166 is a melted impact breccia, a piece from the main mass of about 100g that resides in a European museum.

Another strange meteorite Labenne showed me was Minera Escondida (name pending), a metal-rich carbonaceous chondrite found during Labenne's trip to Chile in 2004. Because of the heft and "skin" of the meteorite, "It was on my desk as a paperweight for 5 years," says Labenne. "Then one day I decided to cut it and have it analyzed, and it turned out to be a new kind of bencubbinite," a weird kind of iron meteorite with many inclusions. The proposed name comes from a copper mine near the find.

Perhaps the oddest specimen I saw is one that Labenne calls his favorite meteorite. ITQIY, a primitive, enstatite achondrite, fell in Western Sahara around 1990, and Luc found a large stone in 2000. The meteorite's fusion crust is dark black and shows flow lines from atmospheric heating during the meteorite's fall. This meteorite is unusual, and it's easy to see why Labenne admires it.

Michael Farmer, meteorite hunter

As I rounded the end of the building at the Hotel Tucson City Center, I found another old meteorite friend. Michael Farmer is an inveterate meteorite hunter and dealer who lives in Tucson. His web site, www.meteoriteguy.com (also www.meteoritehunter.com), has an extensive catalog of space rocks you can explore.



The Fukang meteorite is an example of a pallasite, a meteorite that has olivine crystals (peridot) surrounded by a nickel-iron matrix. In 2000, a Chinese merchant purchased the 2,200-pound (1,000kg) main mass. Tucson meteorite dealer Michael Farmer offers slices of this and other pallasites for sale. Michael Farmer

Farmer is known for his wide selection of stones and reasonable prices.

At the show, Farmer showed me many beautiful specimens. He began by pulling out some spectacular pallasites, the most beautiful of all meteorites due to their olivine inclusions. He had large slices of Fukang, Esquel, Brahin, and Springwater. Farmer's case of pallasites was truly one of the most beautiful collections I saw this year at Tucson — and I probably looked at 100,000 rocks!

Farmer also featured some nice iron meteorites including a huge slice of Nantan from China, etched to show the Widmanstätten pattern. He displayed a gorgeous chunk of Libyan Desert Glass, a tektite that formed from terrestrial sand when an ancient impact fused the sand into glassy masses. He trotted out a huge Murchison meteorite specimen that fell in Australia in 1969 and is scientifically important because it contains amino acids, the building blocks of proteins.

See you in Tucson next year?

My father and I stumbled away from the full tour of meteorites at the Tucson Show tired but enriched with a vast knowledge of the meteorites dealers have out there for sale. Meteorite collecting is such a cool way to get your hands onto tangible pieces of astronomical history.

It's also an area that can be quite affordable: Yes, lunar and martian specimens are out there for anywhere from $500 to $100,000. Yet you can buy common iron meteorites and many stony ones for $25 or $50 each. In a hobby where people usually buy a telescope, some eyepieces, and charts, and then don't have lots of inexpensive toys to buy, why not pick up a space rock or two?

I caution you, though. You may find yourself easily addicted to meteorites and see a growing collection around your house or apartment. It's one of those really nice problems to have. Over and out from Tucson.

See the video interviews the author shot at the Tucson show online at www.Astronomy.com/toc.

Observe 10 hot lunar targets

The Moon's ever-changing face offers something for every amateur astronomer.

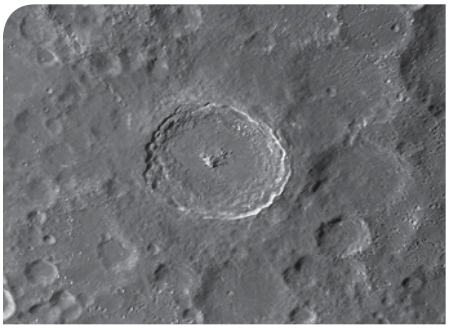
by Michael E. Bakich

Observing the Moon is a great way to hone your skills as an amateur astronomer. As you get more comfortable using your telescope, you'll find it easier to identify small details.

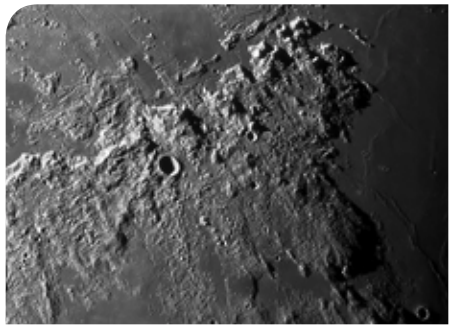
Major phenomena you can view easily are dark sections called maria (the Latin word for "seas"). The material filling the maria is solidified basaltic lava from early periods of lunar volcanism. Lighter areas of the Moon — the highlands — consist of ancient lunar surface rock and materials thrown out during the creation of the impact basins. For an observer, the highlands are a treasure-trove of mountains and valleys, bright areas and shadows.

You'll find most of the Moon's 1,545 craters in the highlands. When observing large craters, note whether you can see rays emanating from them. Rays form when crushed rock sprays out from a meteor impact.

The best time to observe any lunar feature is when it lies close to, or on, the

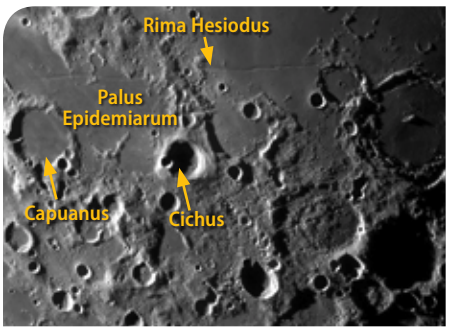


1 Tycho Crater is one of the Moon's most famous features. It has an extensive system of rays that stretches more than 900 miles (1,450 kilometers). At 108 million years old, Tycho is a young crater by lunar standards, hence its freshly cut appearance compared to all the worn craters that surround it. Tycho's diameter is 53 miles (85 km), and it has a depth of 3 miles (4.8 km). The central peaks rise 1 mile (1.6 km) above the floor. Damian Peach

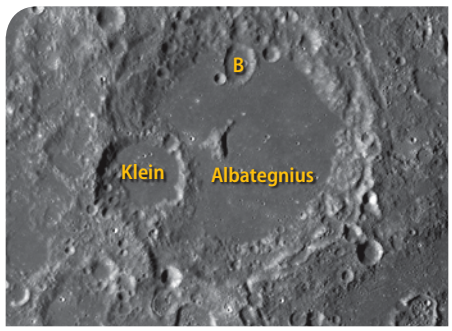


2 Montes Apenninus is a rugged mountain range just north of the Moon's center that stretches some 375 miles (600 km). These peaks, some of which rise 3 miles (5 km) above the surrounding floor, form the southeastern edge of the vast Mare Imbrium basin. The sharp-rimmed, 13.7-mile-wide (22 km) crater in the center of the range is Conon. Smaller (6.6 miles [10.6 km]) Aratus lies to its upper right. Note the many rilles in the image. Paolo R. Lazzarotti

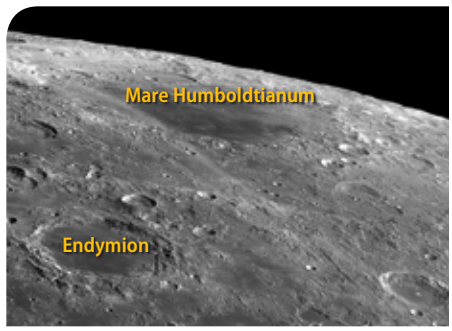
3 Taruntius Crater stretches 34.8 miles (56 km). It lies on the northwestern edge of massive, dark Mare Fecunditatis. Taruntius has a double wall and a prominent, wide central peak. At the northwestern (upper left) edge of the crater, 6.8-mile-wide (11 km) Cameron Crater breaks the outer rim. Asada Crater, which spans 7.5 miles (12 km) lies to the far right in this image. When you observe Taruntius, look for breaks in the lower, inner wall. Damian Peach



4 Rima Hesiodus is not one of the prominent craters pictured here. Instead, your target is the wide cleft that runs through the top half of this image. It starts at Hesiodus Crater (hence the name) and runs for 185 miles (300 km) into Palus Epidemiarum, the Marsh of Epidemics. There, just to the south, you'll find 37-mile-wide (60 km) Capuanus Crater. Be sure to take a look at Cichus Crater (25.5 miles [41 km]) with Cichus C (6.8 miles [11 km]) superimposed on its western wall. Paolo R. Lazzarotti



5 Albategnius Crater is so large that lunar scientists often refer to it as a walled plain or a ring mountain. It measures 84.5 miles (136 km) across and bears many scars of more recent meteor impacts. The most prominent overlapping craters are Klein (27 miles [44 km]), which sits to the southwest, or to the lower left in this image, and Albategnius B (12.4 miles [20 km]), just inside the northern rim at the top of this image. Note that Albategnius' outer wall has a rough hexagonal shape. Damian Peach

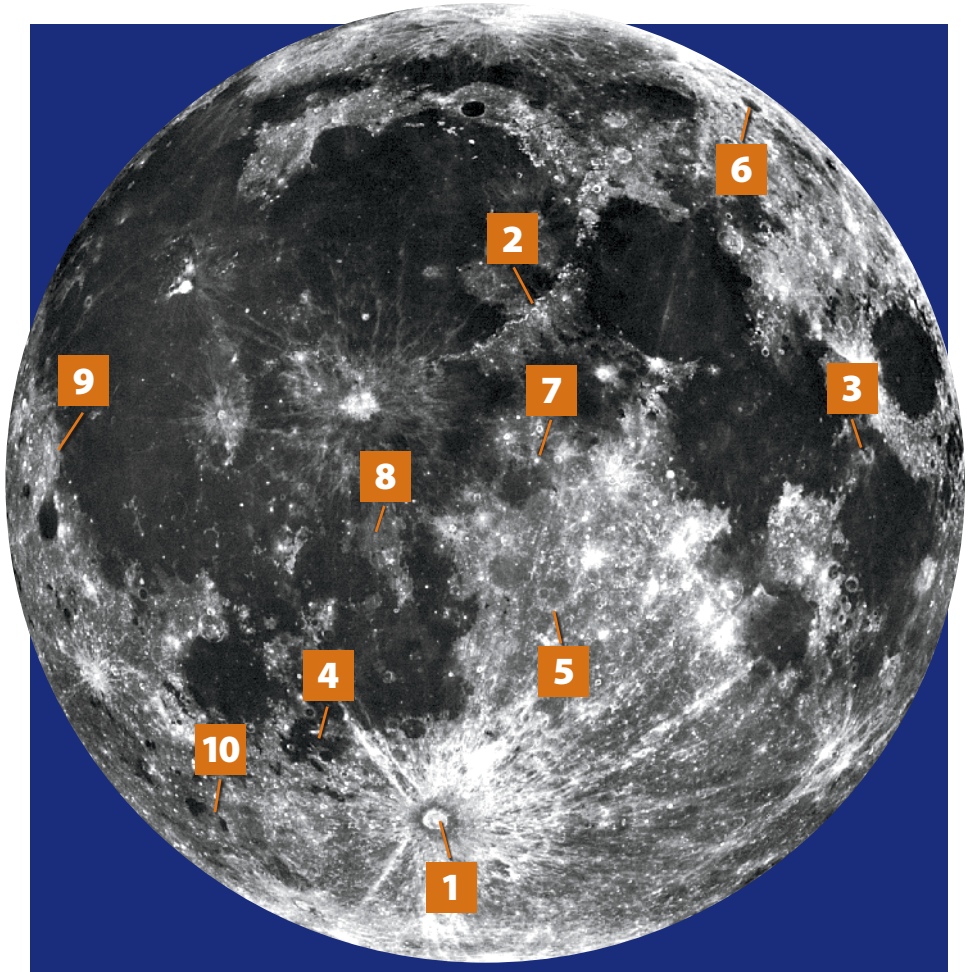


6 Mare Humboldtianum is a feature whose visibility comes and goes because of an oscillatory motion of the Moon called libration. Although one side of our satellite always faces Earth, libration causes us to see roughly 59 percent of the Moon's surface over time. You can spot Mare Humboldtianum at a favorable libration on the Moon's northeastern edge. Whatever the libration, however, you'll be able to observe 78-mile-wide (125 km) Endymion Crater, which is famous for its dark floor. Paolo R. Lazzarotti

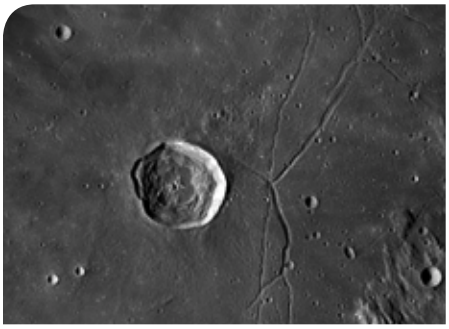
terminator — the border between the Moon's lit and dark parts. Any size telescope will reveal numerous features. I used a 2.4-inch scope for years of lunar observing, and I never ran out of things to see. And unlike with some planetary observing where a phenomenon happens at a specific time, the pressure from the weather is off. If it's cloudy one evening, you can just continue where you left off the next night.

Whether you observe from a bright city or under a jet-black canopy filled with stars, these 10 lunar treats will provide hours of observing pleasure.

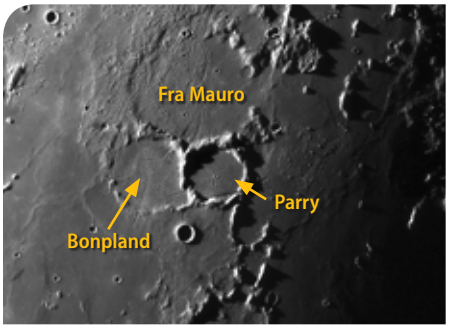
Michael E. Bakich *is an* Astronomy *senior editor.*



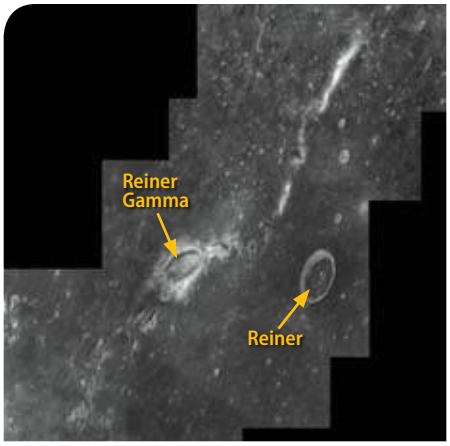
Plotted here are the locations of this story's 10 features. Just match the number with the picture, point your telescope at that spot, and you're on your way to observing 10 hot targets on the Moon. North is up in this image. Lick Observatory



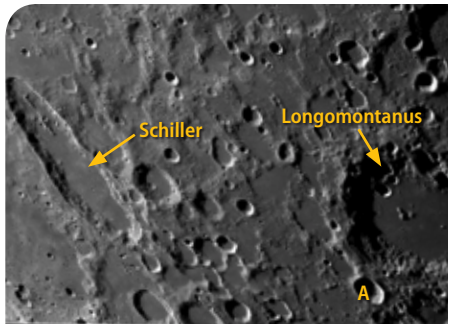
7 **Triesnecker Crater** sits nearly centered on the Moon. It spans 16 miles (26 km), but it's definitely not circular. When most observers point their telescopes here, it's not to observe the crater but rather the Triesnecker Rilles (Rimae Triesnecker). This system is the Moon's best-known system of rilles, and it extends in a north-south orientation for more than 125 miles (200 km). Use a magnification of 200x or more for the best results. Damian Peach



8 **Fra Mauro** Crater spans 59 miles (95 km). The feature is barely visible at the top of this image. It represents the remains of a walled plain. Just to its north is the landing site of NASA's Apollo 14 mission. To the south sit two craters whose walls overlap those of Fra Mauro. Bonpland Crater (37 miles [60 km]) is another old walled plain, and Parry Crater (30 miles [48 km]) has a floor that long ago flooded with dark lava. Look carefully on Fra Mauro's floor for craterlets Fra Mauro E and Fra Mauro P. Paolo R. Lazzarotti



9 **Reiner Crater,** although only 18.6 miles (30 km) in diameter, features prominently within Oceanus Procellarum (the Ocean of Storms) on the Moon's western edge. Although its rim is nearly circular, Reiner appears oval due to the visual effect of foreshortening. Just to Reiner's west, don't miss Reiner Gamma, a bright, flat albedo (reflective) feature that stretches some 43.5 miles (70 km). Some observers have likened Reiner Gamma's appearance to that of a fish. Damian Peach



10 **Schiller Crater** is an elongated lunar impact feature that measures 111 by 44 miles (179 by 71 km). Note Schiller's terraced inner wall. Crank up the magnification, and you'll spot the double ridge along the center of the crater's floor toward the northwest. The large crater (sometimes called a walled plain) at this image's bottom right is Longomontanus (90 miles [145 km]). Longomontanus A sits below and to the left of Longomontanus. Paolo R. Lazzarotti

You can read Michael's previous Moon story, "Explore 12 great lunar targets," at www.Astronomy.com/toc.

The MallinCam takes great images in seconds

Whether you photograph the sky or show live images to a group, this video camera delivers the goods.

by Gary W. Kronk

During the past 4 decades, I have taken more astronomical photographs than I can count. I started in 1971 when I took an old box camera and modified it to take time exposures. A few years later, I moved into 35mm film photography and stuck with it until I graduated to a digital SLR in 2004. Then, in 2006, I started using the MallinCam, and my life would never be the same.

The MallinCam is a video camera that provides great live views of whatever you point your telescope toward. The current product line is the MallinCam Hyper Plus, and it comes in both color and black-and-white models. I have had the black-and-white camera since 2006 and began using the color camera in 2009. Each camera has a resolution of 811 by 508 pixels.

Be aware that U.S. and Canadian customers must order from different dealers. The warranty on a Canadian camera will not be honored for purchasers in the United States.

Several features make these cameras shine. First, the custom-designed high-gain circuitry amplifies the signal from the CCD while still providing a good image. Second, a high-quality Peltier cooler slowly lowers the sensor's temperature to diminish electronic noise and increase sensitivity. Third, a custom-designed hyper circuit board allows light to accumulate on the CCD for up to 56 seconds. And finally, the camera's creator, Rock Mallin, handcrafts and fully tests each camera to ensure it performs up to specs. In short, the camera electronically soups up your telescope.

Images that will blow you away

I typically use these cameras on my 8-inch Meade LX200 telescope, and I know the visual performance of this instrument like the back of my hand. Still, when I first connected the black-and-white MallinCam to the LX200, the view amazed me. My first target was the Crab Nebula (M1), a supernova remnant in Taurus. The live image revealed lots of nebular detail as well as stars fainter than 16th magnitude.

After tweaking the camera settings, I began to acquire images that far exceeded any I had taken before. Using the 7- and 14-second hyper settings, I pushed the limiting magnitude of my images to about 18.5 — nearly 100,000 times fainter than what naked eyes can see. I can observe great detail in deep-sky objects and easily view faint comets. I don't have any trouble picking out several of the moons that orbit Uranus and Neptune.

The MallinCam Hyper Plus video camera delivers deep views of the cosmos in mere seconds. All images by the author

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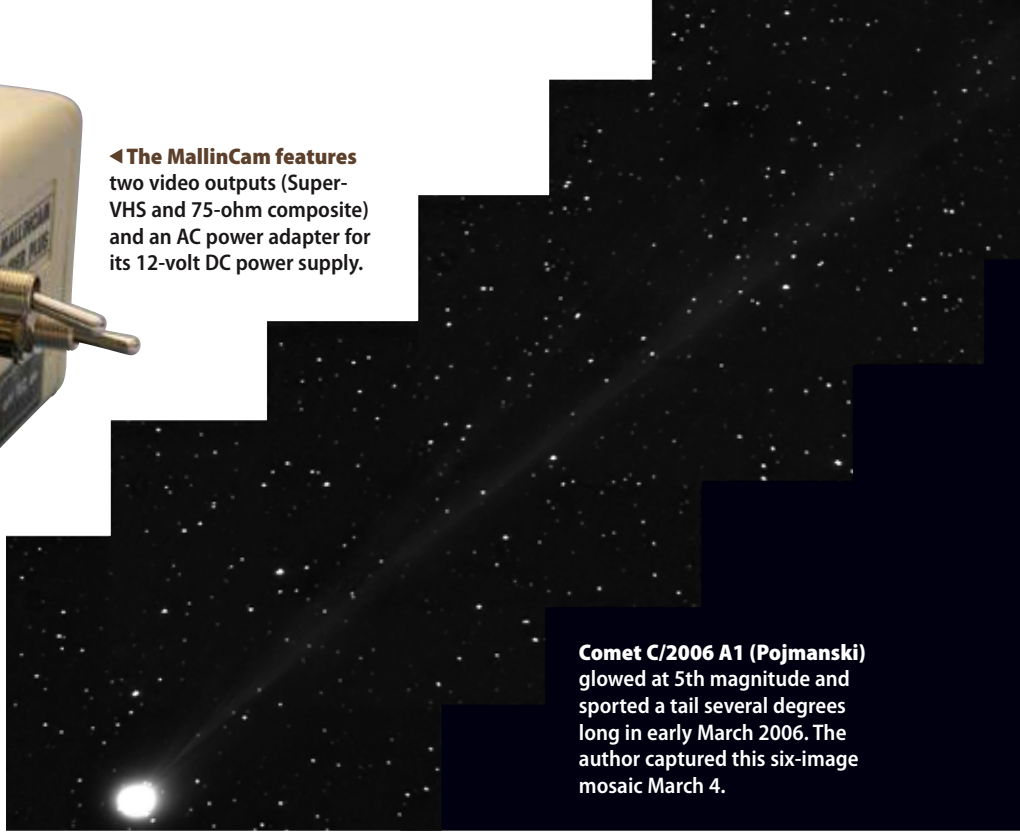
Gary W. Kronk *is an avid amateur astronomer who specializes in observing comets and meteors.*

◀ The MallinCam features two video outputs (Super-VHS and 75-ohm composite) and an AC power adapter for its 12-volt DC power supply.



Comet C/2006 A1 (Pojmanski) glowed at 5th magnitude and sported a tail several degrees long in early March 2006. The author captured this six-image mosaic March 4.

Unfortunately, I do not get great results with the 28- and 56-second hyper settings. But the reason is obvious: The camera greatly enhances the low light-pollution levels around my Illinois observatory. Even so, I have managed to take some decent images with these longer integration modes when using a 2x Barlow lens.

Great for groups

Although I use these cameras primarily for imaging, they prove incredibly helpful for public outreach. With the MallinCam, you don't need a giant telescope to show people exceptional detail in galaxies and nebulae. And, because the live image is fed to a monitor, you can point out different features to a group of onlookers.

I have tried three software packages that enhance the output of these cameras. Because the MallinCam can capture AVI movies, I use the free software package *Registax* to align and stack the images. This program allows my 8-inch scope to reach a limiting magnitude of 19 when using the 14-second integration mode.

The Ring Nebula (M57) in Lyra is a planetary nebula whose gaseous envelope glows as it absorbs ultraviolet light from the central star and re-emits it at visible wavelengths.

Handy AVI from AZcendant Software is easy to use and costs just $39.95. It has a nice preview window that allows you to adjust the brightness and contrast of the image coming from the MallinCam.

The program's main window also has settings for altering the number of frames and how often to shoot. If I set the camera to 7-second integration, I change the numbers in *Handy AVI* so that the camera shoots one frame every 7 seconds. And if I set the camera to 14-second integration, I change the numbers accordingly.

This works well for photographing comets — I can play back the movie and watch the comet slowly glide through the star field. I often show these movies in presentations, and they never fail to impress the audience.

The only downside I've encountered with the MallinCam is a glow in the upper left corner caused by the amplifier. It becomes particularly noticeable during the longer integration modes. Although the company offers instructions on how to minimize this glow, I found an Adobe *PhotoShop* plug-in called *GradientXTerminator* that solves the problem. This $49.95 plug-in comes from Russell Croman Astrophotography. The plug-in is a gradient removal tool that also works great for vignetting problems. In just a few quick and easy steps, the tool gives the image a nice even background that's ready to show off.

I have a lot of fun using these cameras. They are a joy if you want to watch live images through your telescope or show a group the wonders of space. Slew through galaxies in the Virgo cluster or across the Sagittarius Milky Way for scenes you (and they) won't soon forget. And, of course, if you want to do some imaging, these cameras will perform beautifully.

Product specifications

MallinCam Video CCD Observational System
TV system: NTSC (also available in PAL)
Image sensor: Sony ICX418AKL-A Class 1 CCD with Micro Lens Technology (color); Sony ICX428ALL-A EXview HAD Class 1 CCD with Micro Lens Technology (black and white)
Total pixels: 811 (horizontal) by 508 (vertical)
Scanning system: 525 lines, 60 fields/sec (NTSC); 625 lines, 50 fields/sec (PAL)
Shutter: Standard and variable modes from 1/60 to 1/12,000 second
Power supply: 12.1 volts DC at 390 milliamps
Prices: MallinCam Color Hyper Plus, $1,199.95; MallinCam B&W Hyper Plus, $1,099.95

All about the North America Nebula

Scan this giant nebula through binoculars or a telescope, and you'll find more than just dazzling beauty.

by Raymond Shubinski

The North America Nebula (NGC 7000, left) and the Pelican Nebula (IC 5067/70) are easy to locate. They lie approximately 3° east-southeast of the magnitude 1.3 star Deneb (Alpha [α] Cygni, which lies off the image to the upper right). This photograph covers a region of sky that measures 4° by 2.5°. The astrophotographer had to stitch four images together to cover the entire field of view. Adam Block/NOAO/AURA/NSF

On a clear, moonless Northern Hemisphere summer night, the Milky Way cuts a brilliant path from Scorpius and Sagittarius in the south to Cassiopeia in the northeast. Bounding and containing this river of light are the Summer Triangle's three stars, Vega, Altair, and Deneb.

Deneb (Alpha [α] Cygni) is the brightest star in the constellation Cygnus the Swan, and it points the way to an incredible object, the North America Nebula. The name derives from its uncanny resemblance to a map of North America. The nebula even has a prominent "Gulf of Mexico" and "Florida," which add to the effect of cosmic cartography. Astronomers also catalog the North America Nebula as NGC 7000 and Caldwell 20.

Just the nebulous facts

Photographs of the North America Nebula show a huge interstellar cloud of glowing hydrogen. The gas appears red to the camera but greenish-white to the human eye. The object's map-like shape occurs because intervening dust clouds block light from parts of the nebula.

Astronomers classify NGC 7000 as an emission nebula. In such objects, the gas absorbs energy from a nearby hot star. The hydrogen atoms can't hold the energy for long, however, and they release it as light with a reddish glow.

How far away is the North America Nebula? Astronomers aren't sure. Current estimates place it between 1,800 and 2,200 light-years from Earth. As we view it, NGC 7000 lies 3° from Deneb. Some astronomers have theorized that the nebula may lie at about the same distance as this star. If so, it would be closer to the 1,800-light-year distance.

Astronomers already know that Deneb is one of the most distant 1st-magnitude stars in the sky. It shines about 60,000 times more brilliantly than the Sun and has a surface temperature of nearly 16,000° Fahrenheit (8870° Celsius). If Deneb and the nebula are physically related, then this super-star could provide the energy that causes the hydrogen to glow.

During the past decade, some astronomers have cast doubt on any association of Deneb with the North America Nebula. In 2004, researchers Fernando Comeron of the European Southern Observatory and Anna Pasquali of the Institute of Astronomy in Zurich found 2MASS J205551.25+435224.6 — a hot, bright star obscured by the dark dust clouds in front of the North America Nebula. Such a star could energize the hydrogen producing the emission nebula. A great deal depends on the accuracy of the distance measurements.

The nebula itself is huge — 120' by 100'. That makes it nearly 16 times the size of the Full Moon, which explains its low surface brightness. The North America Nebula measures approximately 70 light-years across.

North America history

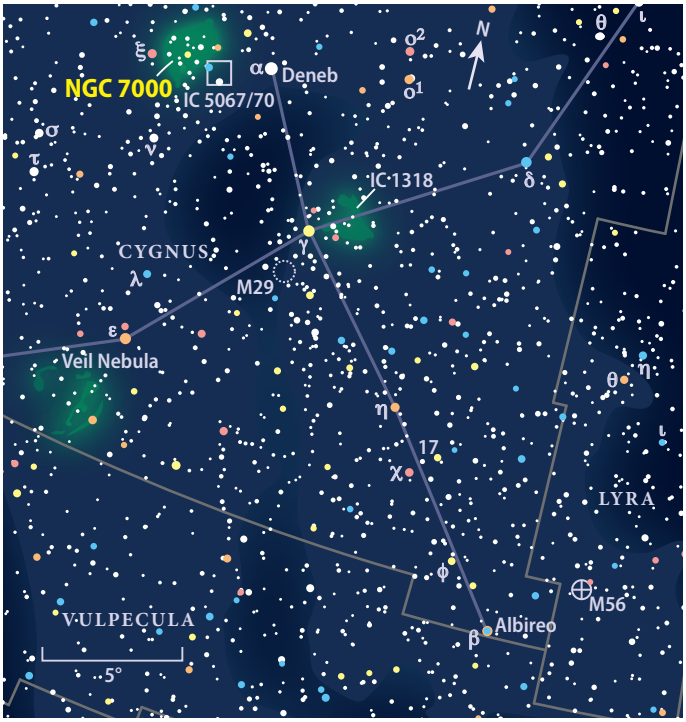
Sir William Herschel (1738–1822), the Hanoverian musician turned British astronomer, discovered the North America Nebula. Observing in the late autumn of 1786, Herschel noted a "faint, extremely large, diffuse nebulosity" October 24, which he cataloged as H V .37. His description matches closely what an

Raymond Shubinski *is an* Astronomy *contributing editor and a longtime deep-sky observer who loves the Northern Hemisphere's summer sky.*

This image of the Pelican Nebula (IC 5067/70) shows a 36'-wide field of view located at the object's northwest rim. Shock fronts trace outflows from stars forming at the nebula's edge. Radiation is eroding the surrounding molecular cloud. In regions shadowed by dense clumps of gas and dust, parts of the cloud survive erosion long enough to produce thin pillars of dusty material. John Bally (U. Colorado)/Bo Reipurth (U. Hawaii)/NOAO/AURA/NSF

This Two Micron All Sky Survey (2MASS) image shows more than you might think. The region pictured surrounds the North America Nebula. The field of view here measures 4.2° by 6.2°. Look closely. Dark patches scattered throughout the image are silhouettes of molecular clouds against the Milky Way backdrop. Because emission nebulosity is generally weak in the infrared, and dust grains do not scatter infrared light efficiently, the diffuse nebulosity is not visible in this image. 2MASS/E. Kopan

In this mapped-color image of NGC 7000, red represents light recorded through a Sulfur-II filter, green stands for Hydrogen-alpha light, and blue corresponds to Oxygen-III emissions. Using different filters reveals details within the nebulosity that are invisible in color images. Dean Salman



The region of Cygnus the Swan near Deneb (Alpha [α] Cygni) contains the North America Nebula (NGC 7000), the Pelican Nebula (IC 5067/70), and many other deep-sky splendors. *Astronomy*: Richard Talcott and Roen Kelly

observer would see through a telescope/eyepiece combination that gives a wide field of view.

Some 40 years later, William's son, Sir John Herschel (1792–1871), rediscovered the nebula. It appeared to him as a white smudge 3° from Deneb. Were William and John Herschel truly the first to see this object? Many contemporary observers claim to have no problem seeing this smudge without optical aid. It seems possible that a Babylonian astronomer glimpsed the nebula from a tower in the Persian Desert thousands of years ago.

German astronomer Maximilian Franz Joseph Cornelius Wolf (1863–1932) was the first to photograph this object, on December 12, 1890. He dubbed it the America Nebula, from which its current moniker derives.

Observing NGC 7000

I have scrutinized 40 years of my observing notebooks and can't boast of ever seeing the North America Nebula without binoculars. Some observers who have succeeded use a nebula filter held in front of their eye to dim the surrounding stars and increase the object's contrast.

As a whole, NGC 7000 appears best through binoculars or telescopes at low power. However, at higher magnifications, you can spot a bounty of other interesting objects.

Just off the continent's East Coast, you'll find the Pelican Nebula (IC 5067/70), a gas cloud which seems to be eyeing the Florida peninsula. The magnitude 5.1 star 56 Cygni rides the Pelican's back. The Pelican is fainter than the North America, and — no matter how good an observer you are — it definitely requires optical aid to view.

Both nebulae are areas of intense star formation. You can spot three open clusters — magnitude 8.7 Collinder 428, magnitude 10.0 NGC 6996, and magnitude 10.0 NGC 6997 — against the gaseous background. William Herschel cataloged NGC 6997 on October 24, 1786, the same night he described the faint nebulosity of the main nebula. NGC 6997 is the easiest to pick out from among the background stars.

Recently, confusion arose about the identifications of NGC 6996 and NGC 6997. The first of these two clusters lies near the continent's Maine coastline; NGC 6997 lies in the upper Midwest. Collinder 428 sits on the West Coast at about the state of Washington's position. Its stars appear to run in parallel lines.

The North America Nebula gained additional notoriety in early March 1997. At that time, Comet C/1995 O1 (Hale-Bopp) was dazzling observers around the world. When the comet was about the same distance from Earth as the Sun, it passed nearly in front of the North America Nebula, making a spectacular red, white, and blue display.

It's important to remember just how two-dimensional such images are. When Hale-Bopp passed in front of the nebula, its light took only 8 minutes to reach Earth. The light from the nebula, on the other hand, had been traveling to our eyes since the fall of the Roman Empire!

The entire region around the tail of Cygnus holds many treasures in addition to the North America Nebula. Be sure to catch them this summer while they lie high in the sky.

See more images by astrophotographers of the North America Nebula and the Pelican Nebula at www.Astronomy.com/toc.

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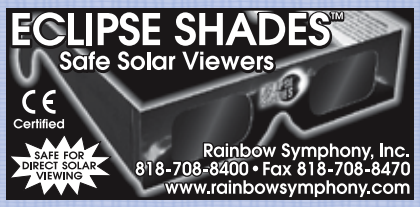

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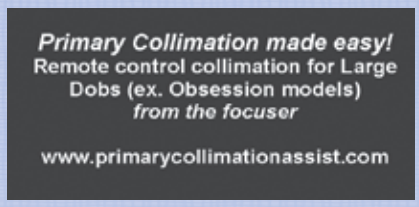
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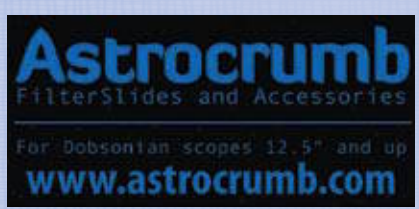

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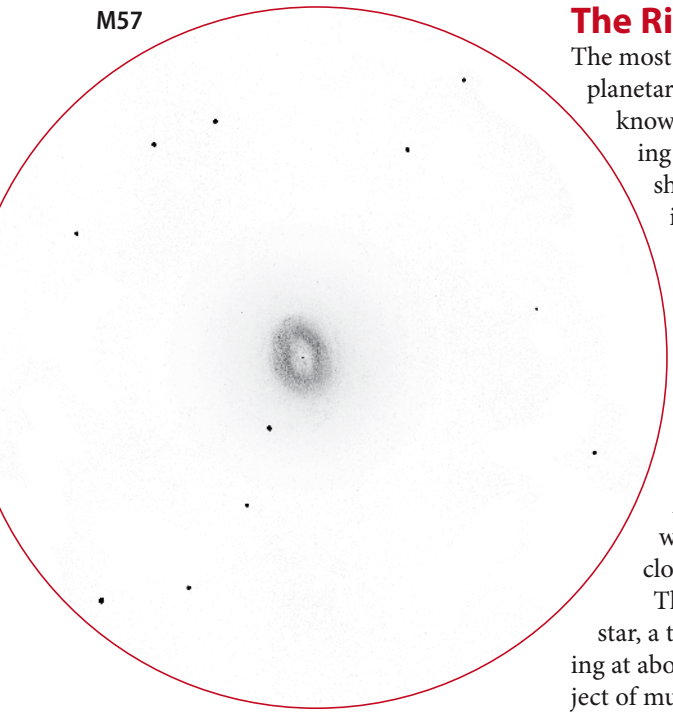
Deep-sky Showcase

Astronomy's *editor sketches two of his favorite objects.* **by David J. Eicher**

The Ring Nebula and NGC 6726/7

M57



The Ring Nebula sketched by David J. Eicher using an 8-inch f/10 SCT at 100x.

The Ring Nebula (M57)

The most observed object in Lyra is the planetary nebula Messier 57, popularly known as the Ring Nebula. Measuring some 70" across (a faint outer shell extends to 230") and glowing at magnitude 8.8, M57 is a small but easily recognizable "smoke ring" of hazy light in even a 3-inch telescope. A 6-inch scope operating at high power clearly shows the central dark hole, which is actually the thinnest part of a large spheroidal shell of gas, but M57 appears as a ring because we see the thickest part of the cloud of nebulosity.

The visibility of M57's central star, a tiny bluish dwarf weakly glowing at about 15th magnitude, is the subject of much debate. Curiously, several observers have reported seeing this faint speck inside the Ring using telescopes as small as 5 inches in aperture. Others have failed to see it through much larger telescopes. The star may be slightly variable or possibly is extremely sensitive to observing conditions.

M57

Mark Hanson

Designations: M57, NGC 6720
Position: 18h54m, 33°02' (2000.0)
Constellation: Lyra
Magnitude: 8.8
Size: 70"
Distance: 2,300 light-years

NGC 6726/7

Filippo Ciferri

Designation: NGC 6726/7
Position: 19h02m, –36°53' (2000.0)
Constellation: Corona Australis
Magnitude of illuminating star: 7.2
Size: 8' by 8'
Distance: 400 light-years

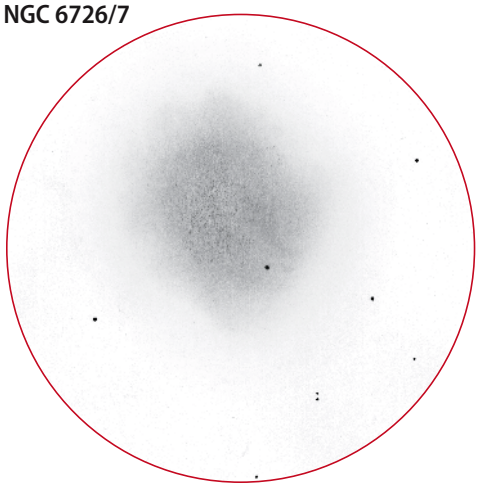
David J. Eicher *is the editor of* Astronomy. *He has observed and sketched deep-sky objects for 34 years.*

NGC 6726/7

A great complex of nebulosity in the southern sky rarely gets the attention of observers — but it should. A field of nebulosity carries the NGC numbers 6726 and 6727, a double nebula if you will, and — nearby — NGC 6729. NGC 6726/7 is a reflection nebula shaped like a figure eight that stretches 8' across. The nebula's southwestern section contains a 7th-magnitude pure-white star, and the northeastern part holds the erratic variable star TY Coronae Australis. This unusual star fluctuates irregularly between magnitudes 8.8 and 12.6; you can check its magnitude against that of a 7th-magnitude star located nearby.

About 4.7' southeast of the double nebula is the even stranger nebulosity NGC 6729. This patch of gray light is 1' long and appears as a tiny, misty comet complete with a fuzzy tail. Embedded within this object is the bizarre nebular variable R Coronae Australis. This star's fluctuations in light change the visible size of the nebulosity, much as is the case with Hubble's Variable Nebula (NGC 2261) in Monoceros.

NGC 6726/7



NGC 6726/7 sketched by David J. Eicher using an 8-inch f/10 SCT at 50x.

reader gallery

The Boogie Man (LDN 1622) (7.2-inch Takahashi E-180 Newtonian reflector at f/2.8, SBIG ST-10 CCD camera, Hα/GB image, with exposures of 390, 35, and 35 minutes, respectively) • Daniel B. Phillips, Oceanside, California

The Southern Owl Nebula (PK 283+25.1) in Hydra is a magnitude 12 planetary nebula that measures 2' across. (14.5-inch RC Optical Systems classical Cassegrain telescope at f/8.2, Apogee U16M CCD camera, RGB/Hα/OIII image with exposures of 40, 40, 40, 220, and 400 minutes, respectively) • Don Goldman, Orangevale, California

Be afraid

The Boogie Man is a dark nebula in Orion. In 1962, American astronomer Beverly T. Lynds included it in her *Catalog of Dark Nebulae*. The catalog contains 1,791 entries based on her study of the National Geographic–Palomar Observatory Sky Survey photographic plates. The Boogie Man now carries the catalog designation LDN (for Lynds Dark Nebula) 1622. We see this object because the dark cloud of dust and cold gas lies silhouetted in front of a faint reddish emission nebula. The current distance estimate to LDN 1622 is a scant 500 light-years.

▼ **NGC 4216** dominates this trio of spiral galaxies. It, and NGC 4206 to its lower right, lie in Virgo. At the upper left, NGC 4222 floats in Coma Berenices. (12.1-inch RC Optical Systems Ritchey-Chrétien telescope at f/9.3, SBIG STL-11000 CCD camera, LRGB image with exposures of 6, 1, 1, and 1 hours, respectively) • Jeff Lunglhofer, Chula Vista, California

▲ **Open cluster NGC 7209** in the constellation Lacerta the Lizard lies in a rich Milky Way star field. The cluster shines at magnitude 7.7 and measures 25' across. (6.4-inch Astro-Physics AP160 StarFire EDF apochromatic refractor at f/7.5, SBIG ST-10XME CCD camera, LRGB image with 30-minute exposures through each filter) • Anthony Ayiomamitis, Athens, Greece

Sharpless 2–308 in Canis Major is a glowing nebula powered by energetic stellar winds from a Wolf-Rayet star (the bright blue star near the image's center). This object lies 5,200 light-years away and has a diameter of 60 light-years. (8-inch Maksutov-Newtonian telescope at f/4, SBIG ST-10XME CCD camera, SII/Hα/OIII image with data converted from SII to blue, Hα to red, and OIII to green, 9 hours total exposure time) • Dean Salman, Tucson, Arizona

reader gallery

Send your images to: *Astronomy* Reader Gallery, P. O. Box 1612, Waukesha, WI 53187. Please include the date and location of the image and complete photo data: telescope, camera, and exposure information. Submit images by e-mail to readergallery@Astronomy.com.

RCW 19 is part of a giant molecular cloud in the southern constellation Puppis the Stern. The massive cloud lies some 10,700 light-years away. The "RCW" designation stands for (Alex) Rogers, (Colin) Campbell, and (John) Whiteoak, three astronomers working at Mount Stromlo Observatory in Australia who published a catalog of 182 southern nebulae in 1960. (6.2-inch Astro-Physics 155 EDF apochromatic refractor at f/5.4, FLI ProLine KAF-16803 CCD camera, L/Hα/RGB image with exposures of 170, 400, 180, 140, and 170 minutes, respectively) • Thomas V. Davis, Inkom, Idaho

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PowerSeeker, two achromats, 70mm and 80mm: German equatorial mounts. **$119.95 to $144.95**.

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EXPLORE SCIENTIFIC 3 refractors

Explore Scientific is a new company, but they have quickly gotten a reputation for high quality at reasonable prices. Here are the 3 Explore Scientific refractors . . .

ED Triplets, three models, 80mm to 127mm: apochromatic optical tubes only. **$799 to $1999**.

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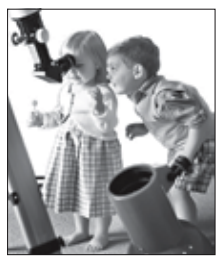

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